PROCEEDINGS OF A WORKSHOP ON THE LAKE STURGEON (ACIPENSER FULVESCENS)

1987
ONTARIO FISHERIES
TECHNICAL REPORT SERIES
NO. 23

Ontario
Ministry of Natural Resources
Hon. Vincent G. Kerrio
Minister
Mary Mogford
Deputy Minister

87-04852/

PROCEEDINGS OF A WORKSHOP ON THE LAKE STURGEON (ACIPENSER FULVESCENS)

1987
ONTARIO FISHERIES
TECHNICAL REPORT SERIES
NO. 23

C.H. Olver, Editor

Ontario
Ministry of Natural Resources
Hon. Vincent G. Kerrio
Minister
Mary Mogford
Deputy Minister

ISSN 0227-986X
ISBN 0-7729-2107-5

© 1987, Queen's Printer for Ontario

Printed in Ontario, Canada

The Ontario Fisheries Technical Report Series has been established by the Ontario Ministry of Natural Resources to provide for the broad dissemination of internal reports and reviews that are of relevance to provincial problems and issues in fisheries management and research.

Distribution of this series is limited. Requests for copies should be addressed to the Ontario Ministry of Natural Resources, Fisheries Branch, 99 Wellesley St. West, Toronto, Ontario M7A 1W3.

Current publications of the Ontario Ministry of Natural Resources, and price lists, are obtainable through the Ministry of Natural Resources Public Information Centre, Room 1640, Whitney Block, 99 Wellesley Street, West, Toronto, Ontario M7A 1W3 (personal shopping and mail orders).

And:

Personal shopping: Ontario Government Bookstore, Main Floor, 880 Bay Street, Toronto.

Mail Orders: MGS Publication Services Section, 5th Floor, 880 Bay Street, Toronto, Ontario M7A 1N8. Telephone 965-6015. Toll free long distance 1-800 268-7540, in Area Code 807 dial 0-Zenith 67200.

Cheques or money orders should be made payable to the Treasurer of Ontario, and payment must accompany order.

CONTENTS

	Page
Preface	iv
Introduction to the proceedings of a workshop on the lake sturgeon (*Acipenser fulvescens*). . . . . C.H. Olver	1
The lake sturgeon (*Acipenser fulvescens*) in Ontario . . . . . C.S. Brousseau	2
Biology and population dynamics of lake sturgeon (*Acipenser fulvescens*) from the Frederick House, Abitibi and Mattagami rivers, Ontario . . . . . D.A. Payne	10
Biology and management of the lake sturgeon (*Acipenser fulvescens*) in the Groundhog and Mattagami rivers, Ontario . . . . . A.M. Nowak and C.S. Jessop	20
Biology of the lake sturgeon (*Acipenser fulvescens*) in the Kenogami River, Ontario. . . . . A.P. Sandilands	33
Biology and management of the lake sturgeon in the Moose River, Ontario . . . . . R.W. Threader and C.S. Brousseau	47
The lake sturgeon (*Acipenser fulvescens*) fishery of Lake of the Woods, Ontario . . . . . T.S. Mosindy	48
Biology and exploitation of lake sturgeon (*Acipenser fulvescens*) in the Québec waters of the Saint-Laurent River . . . . . P. Dumont, R. Fortin, G. Desjardins and M. Bernard	57
Age determination of lake sturgeon (*Acipenser fulvescens*) by use of the marginal pectoral fin ray. . . . . N.C. Wilson	77
Lake sturgeon (*Acipenser fulvescens*) management and culture in Minnesota and Michigan. . . . . E.R. Anderson	84
Management considerations	85
Considerations for the management of lake sturgeon (*Acipenser fulvescens*) commercial fisheries in Ontario. . . . . M.L. Hart	85
Management of lake sturgeon (*Acipenser fulvescens*) as a sport fish in Ontario. . . . . J. Atkinson	91
Enforcement implications for management of lake sturgeon (*Acipenser fulvescens*) in Ontario. . . . . W.J. Cook	95
Appendix	
Appendix A. Workshop participants	97

PREFACE

The publication of the *Proceedings of a Workshop on the Lake Sturgeon* (*Acipenser fulvescens*) is a special issue of the Ontario Fisheries Technical Report Series. Due to the multi-paper content of this publication, the format of this report has been modified from the standards established for this series.

The citation for this report is:

Ontario Ministry of Natural Resources. 1987. Proceedings of a workshop on the lake sturgeon (*Acipenser fulvescens*). Ont. Fish. Tech. Rep. Ser. No. 23. 99 p.

Keywords: lake sturgeon, workshop proceedings, reports, management considerations

INTRODUCTION TO THE PROCEEDINGS OF A WORKSHOP ON THE LAKE STURGEON (*ACIPENSER FULVESCENS*)

C. H. Olver
Ontario Ministry of Natural Resources, Box 9000, Huntsville, Ontario P0A 1K0

A workshop to discuss the biology and management of the lake sturgeon (*Acipenser fulvescens*) was hosted by the Northern Region of the Ontario Ministry of Natural Resources at Timmins, Ontario, on February 27 and 28, 1986. It was organized and chaired by C.S. Brousseau, Regional Fisheries Biologist, Northern Region.

Large river inventories conducted in the Northern Region in the past few years indicated that lake sturgeon were found in several rivers, but very little was known about their life history, population dynamics, or potential yield. During the same period there has been an increasing interest in both sport and commercial fishing for sturgeon. In response to this increased demand, the Northern Region has conducted several biological studies on riverine stocks of lake sturgeon since 1980.

In other parts of Ontario, lake sturgeon have shown a history of over-exploitation that resulted in the collapse of several stocks which have not recovered under existing management practices. Concern has been expressed by fisheries managers that present regulations are not adequate to manage lake sturgeon on a sustained yield basis. In order to prevent further declines in stocks, new management approaches are required.

The objectives of the workshop therefore, were: to assimilate historical and recent information on the lake sturgeon; to examine the status of commercial and sport fisheries; to review the effectiveness of existing management practices; and, to develop guidelines for the management of the lake sturgeon, with particular reference to the province of Ontario.

Most of the presentations focused on the biology and management of riverine stocks in northern Ontario, but contributions also included a study of the lake sturgeon in the Quebec waters of the St. Lawrence River and in Lake of the Woods in northwestern Ontario. In addition, there was a review of sturgeon management and culture in Minnesota and Michigan and an examination of the methods used for aging lake sturgeon.

Following the presentation of the papers, three working groups were formed to discuss management of lake sturgeon relative to sport fishing, commercial fishing and enforcement. The results of these deliberations, as reported by the convenors of each working group, are included in the proceedings under Management Considerations.

THE LAKE STURGEON (*ACIPENSER FULVESCENS*) IN ONTARIO

C. S. Brousseau
Ontario Ministry of Natural Resources, Box 3000, Cochrane, Ontario POL 1C0

Lake sturgeon (*Acipenser fulvescens*) populations in Ontario have declined rapidly since the turn of the century. The maximum commercial harvest was over 816,000 kg in 1885, but has been less than 10,000 kg in recent years. Overfishing and habitat degradation have both contributed to this decline. The sport fishery for lake sturgeon has also increased in the past few years, and there are only a few areas left in the province where populations are still abundant enough to provide angling. Long-term yields of lake sturgeon have been quite low (<0.04 kg ha^{-1}). Their slow rate of growth and late age to maturity (15-25 years) makes them extremely vulnerable to overexploitation. Yields of only about 0.2 kg ha^{-1} can be expected from unexploited populations in good habitat. Current regulations are not adequate to protect the remaining fisheries or rebuild depleted ones. Management must consider brood stock protection and the slow turnover rate if populations are to be maintained. The future for lake sturgeon in Ontario is bleak unless significant changes are instituted immediately.

INTRODUCTION

The lake sturgeon (*Acipenser fulvescens*) has had a long and varied history in Ontario. Early settlers considered the lake sturgeon unfit for human consumption. The fish destroyed their nets and when caught were often thrown onto the shore to rot. In the late 1800s, this situation changed as the flesh and eggs were found to be edible and other uses for the fish were found. The demand for lake sturgeon increased and with it an increase in fishing pressure.

Habitat degradation and commercial exploitation of this species, which has a very low sustainable yield, have seriously reduced lake sturgeon populations across Ontario. Lake sturgeon now demands a higher commercial price than any other fish species in the province and there is an increasing demand by anglers. Harkness and Dymond (1961) summarized much of the data on lake sturgeon up until that time. This paper updates information on lake sturgeon in Ontario in regard to their distribution, commercial and sport fisheries, yield and habitat changes. A prognosis for the future based on current trends is presented.

DISTRIBUTION

The lake sturgeon is the only one of the five Canadian species of the sturgeon family found in Ontario. The lake sturgeon has one of the widest ranges of freshwater fish in North America (Houston 1984). Ontario range maps show that lake sturgeon occur throughout the province in all primary watersheds (Scott and Crossman 1973) indicating that it is a common, widespread fish throughout its range.

The distribution of lake sturgeon, however, is sporadic across Ontario. A recent survey of the 47 administrative districts of the Ontario Ministry of Natural Resources (OMNR) shows that lake sturgeon are not present in nine districts; rare in 28 districts; and common in only 10 districts (Fig. 1) where they are restricted to only a few large lakes and rivers. It would appear that there are only about 100 water bodies in Ontario that support lake sturgeon. Although they occur in the Great Lakes and some large northern inland waters, their numbers have been greatly reduced since the turn of the century.

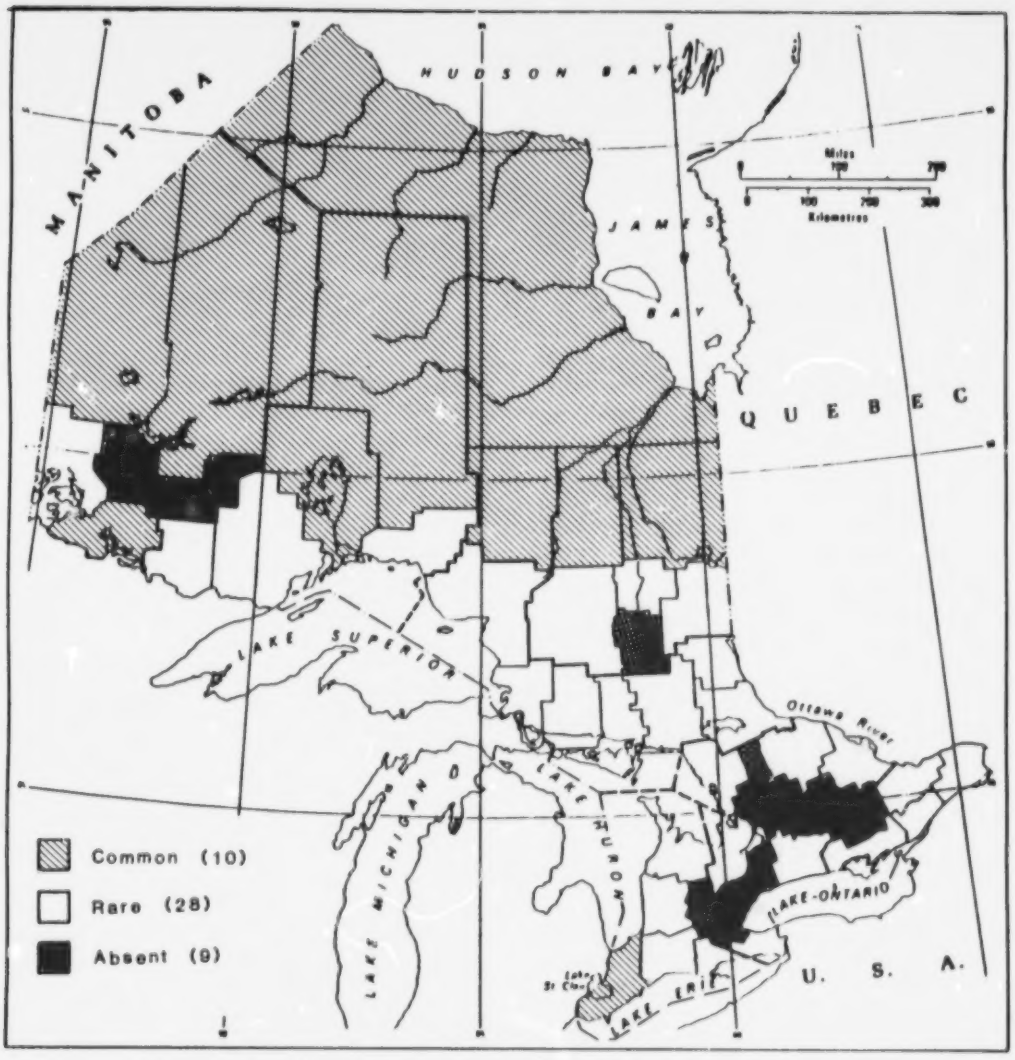

Fig. 1. The distribution of lake sturgeon in Ontario by Ministry of Natural Resources districts.

THE COMMERCIAL FISHERY

The Ontario lake sturgeon commercial fishery has undergone dramatic changes throughout its history. Prior to 1860, there was no market for sturgeon and they were considered a nuisance by commercial fishermen as they destroyed nets set for other species. When caught, they were often clubbed and thrown back into the water or left on the banks to spoil. At Amherstburg, Ontario, they were even stacked like cordwood and used to fire steamboat boilers on the Detroit River (Scott and Crossman 1973). In several areas, access to shallow creeks used for spawning was blocked off (Cusson 1955).

After 1860, the desirability of sturgeon increased in the United States as the smoked flesh became popular and other uses were discovered for the fish. Oil from the flesh was used in paint manufacture, isinglass was made from the swim bladder, leather from the skin and the eggs used for caviar (Cusson 1955).

Their popularity soon spread to Ontario and after 1872 the commercial harvest of sturgeon increased rapidly (Fig. 2). By 1895, the commercial harvest in Ontario peaked at over 816,000 kg with most of the harvest coming from the Ontario portion of the Great Lakes (Fig. 3). In only a few years the populations in the Great Lakes declined rapidly as did the total sturgeon har-

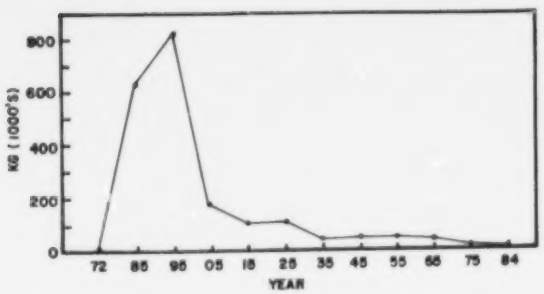

Fig. 2. The commercial harvest of lake sturgeon in Ontario, 1872-1984.

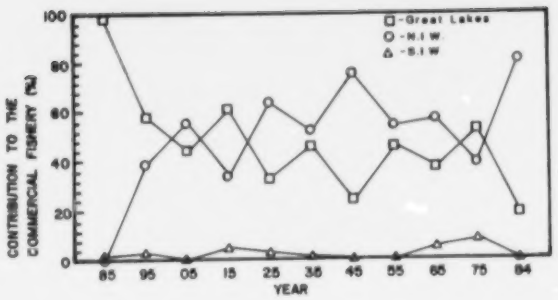

Fig. 3. Relative contribution by area, to the lake sturgeon commercial fishery in Ontario, 1885-1984.

vest for the province. The combined harvest from the Ontario and United States waters of Lake Erie fell from over 2.3 million kg in 1895 to less than 0.45 million kg 10 years later. In 1984, the harvest of lake sturgeon from Lake Erie was a mere 35 kg. By 1950, the harvest from Lake Huron was only 3% of the maximum catch and 2% for lakes Ontario and Superior (Harkness and Dymond 1961).

By the turn of the century, Great Lakes populations had declined, but new fisheries opened up in northern Ontario and contributed about half of the total provincial catch (Fig. 3). Fisheries on Lake of the Woods, Lake Nipissing and Lake Nipigon produced over 318,000 kg or 39% of the provincial harvest in 1895. These fisheries soon followed the same scenario as those on the Great Lakes: an initial rapid increase in harvest, a very short peak and a rapid and permanent decline.

Fig. 4 shows the commercial harvest from Lake Nipissing from 1900 to 1980. From 1903 to 1908, the harvest fell from a high of over 86,000 kg to about 36,000 kg in 1908, when the fishery was closed due to a gill net ban (Young and Love 1970). A pound net fishery established in 1918 harvested about 44,000 kg. By 1930, the harvest had dropped to about 1400 kg, and since then the fishery has not recovered. The current lake sturgeon quota on Lake Nipissing is 900 kg, but it is not taken (C. R. Jorgenson, OMNR, North Bay, Ont. P1B 8K7, pers. comm.).

A similar situation occurred in the Lake Nipigon fishery (Fig. 5). From

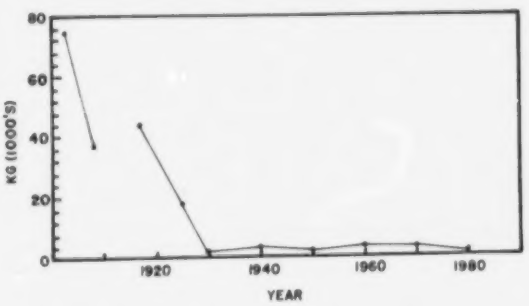

Fig. 4. The commercial harvest of lake sturgeon in Lake Nipissing.

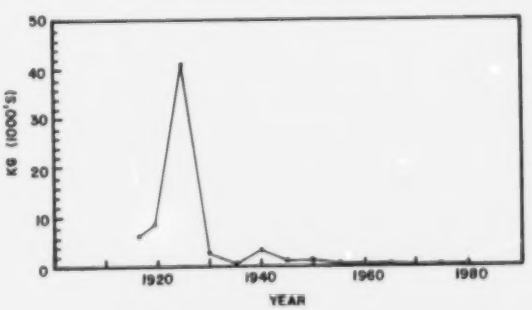

Fig. 5. The commercial harvest of lake sturgeon in Lake Nipigon.

1917 to 1925, the harvest rapidly increased to over 40,000 kg, but by 1930 it was less than 5000 kg. Since 1960, the harvest of lake sturgeon from Lake Nipigon has not exceeded 500 kg and in 1980 only one fish was harvested.

This same scenario has occurred in most lake sturgeon commercial fisheries

in the province. Initial, relatively high yields were followed by quick, rapid and permanent declines. The 1984 Ontario commercial harvest of 7,940 kg came primarily from a small residual fishery on Lake Huron (1,295 kg) and northern inland waters (6,515 kg). This represents <0.01% of the maximum Ontario catch.

The importance of Lake of the Woods, Lake Nipissing and Lake Nipigon to the total commercial catch from northern inland waters is shown in Fig. 6. Between 1895 and 1935, these three lakes provided the majority of the harvest from northern inland waters; all three peaking at different periods. After 1935, the harvest from these lakes became insignificant and new fisheries were opened in other, smaller water bodies.

There are currently no sturgeon waters in Ontario that have not been impacted by exploitation (Houston 1984). The harvest of lake sturgeon in Ontario will continue to be less than 10,000 kg yr^{-1} and may decline if the populations collapse in presently licenced waters.

The commercial harvest of lake sturgeon in Ontario is controlled by licence conditions such as quotas, type of gear, gill net mesh size and length restrictions, hook limitations, minimum size limits and closed seasons. Of these restrictions, only quotas have the capability of controlling harvests. In 1984, 23 districts issued 98 commercial fishing licences for lake sturgeon. The quotas totalled approximately 27,500 kg but only 7,940 kg were harvested. The current quotas are too high as the harvest appears to be more a lack of fish than market price. In 1984, the price of sturgeon ranged from \$3.30 to \$9.90 kg^{-1} ($\bar{x}$ = \$6.18), while caviar reached a high of \$66.00 kg^{-1}.

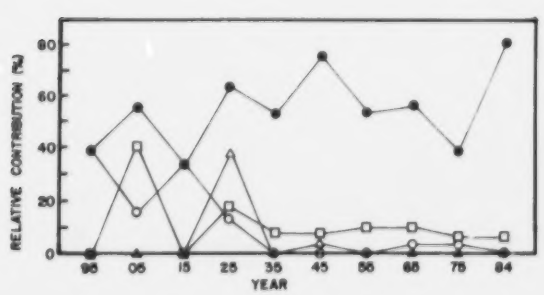

Fig. 6. The relative contribution of the Lake of the Woods (o), Lake Nipissing (□) and Lake Nipigon (Δ) to the total lake sturgeon commercial harvest from northern inland waters (●), 1895-1984.

Gear limitations and closed seasons only make the fishermen less efficient. Mesh size restrictions and minimum size limits force fishermen to harvest the mature portion of the population; the segment that contributes to recruitment. The future of Ontario's lake sturgeon commercial fishery is bleak unless major changes are instituted immediately.

THE SPORT FISHERY

The lake sturgeon has not traditionally been considered a sport fish in Ontario. Historically, lake sturgeon were taken by commercial fishermen and most of the angler-caught sturgeon were taken incidentally. Its size and uniqueness, however, have always attracted some people to attempt to catch a sturgeon on rod and reel and the popularity of lake sturgeon as a sport fish, particularly in northern Ontario, has increased in recent years (Nowak and Jessop 1987).

Most angler-caught sturgeon are in the 5-10 kg range, although fish over 20 kg are caught each year. The largest recorded lake sturgeon caught in Ontario weighed 140.6 kg and was 229 cm in length. This specimen was taken by a commercial fisherman in Batchewana Bay, Lake Superior, in 1922. A possible authentic Ontario angling record may be a 104 kg fish, 203.2 cm in length caught in the Niagara River in 1946 (Scott and Crossman 1973).

In 1984, the estimated angler harvest of lake sturgeon was 9,185 kg, over 1,000 kg greater than the commercial harvest. Lake sturgeon were caught by anglers in 26 OMNR districts (Fig. 7). In 17 districts where it is an incidental species, an estimated 410 kg of lake sturgeon were harvested. In the nine districts where sturgeon are considered a target species, 8,775 kg were

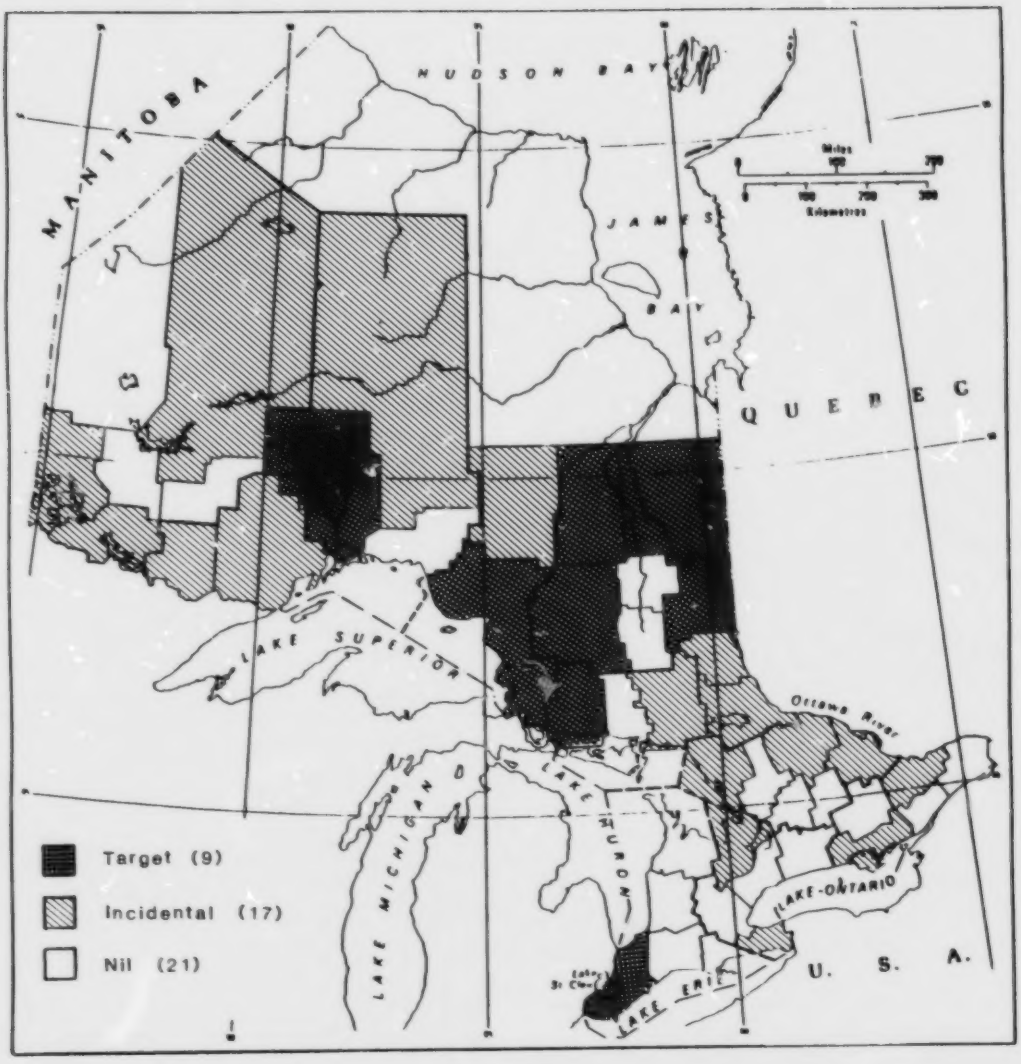

Fig. 7. The status of lake sturgeon as a sport fish in Ontario by Ministry of Natural Resources districts.

harvested. In Kapuskasing District, about 4,600 kg of sturgeon were harvested in the Groundhog River. Chatham District had the second highest sport fish catch of about 2,000 kg. Approximately 72% of the sport harvest of lake sturgeon in 1984 occurred in these two districts.

Since sturgeon feed almost exclusively on very small organisms they obtain from the bottom by means of their protrusible, tubelike mouth, most sturgeon are caught by still-fishing. Most anglers who target for sturgeon use large hooks, baited with live bait and weighted so that the hook is at or near the bottom. Common baits include minnows, worms, crayfish, sucker meat and dough balls. Even liver and hard-boiled eggs are used.

The lake sturgeon, although not spectacular fighters, stay near the bottom making long sweeping runs. They occasionally surface and then head for the bottom again. A 10 kg sturgeon caught on light tackle may take more than an hour to land. Their size and stamina are attracting an increasing number of anglers each year.

Present sport fishing regulations in Ontario include a creel limit of one fish, closed seasons in some areas, usually around the four weeks associated with spawning and a minimum size limit

of 114 cm total length in fishing divisions 21 and 22 in northwestern Ontario. Recently, a sanctuary on the Groundhog River, aimed at reducing angling pressure, has been recommended (Nowak and Jessop 1987).

In the state of Washington, a harvested slot-size limit has been established on the green sturgeon (*Acipenser medirostris*) and the white sturgeon (*A. transmontanus*) in some rivers. The minimum size limit varies from 91.4-121.9 cm and the maximum size limit is 182.8 cm. Anglers are allowed to keep sturgeon within the slot up to the daily bag limit of 2 or 3 fish. These regulations are designed to protect the brood stock, as the females of these two species do not mature until they are greater than 180 cm. This system has worked well in maintaining viable sport fish populations (G. Kreitman, Col. River Res. Lab., Battleground, WA 98604, pers. comm.).

YIELD

Although commercial yields of sturgeon were initially high (Houston 1984), the sustainable yield is low compared to other species in Ontario. The maximum lake sturgeon yield from the Great Lakes and three northern inland waters was as follows:

Lake	Maximum yield (kg ha^{-1})
Superior	.01
Huron	.07
Erie	.91
Ontario	.13
Lake of the Woods	.21
Nipigon	.10
Nipissing	.99

Maximum yield averaged 0.28 kg ha^{-1} for the four Great Lakes and 0.43 kg ha^{-1} for the three northern inland waters. In all cases, these maximum yields occurred only for one year, after which they declined very rapidly. The sustainable yield was surpassed at values much below these levels. Following the peak yield, the long-term yield dropped to <0.04 kg ha^{-1} with several lakes declining to <0.001 kg ha^{-1}. Since all commercial fisheries in Ontario for sturgeon followed the same pattern, it is difficult to determine the sustainable yield.

MacRitchie (1983) calculated that riverine lake sturgeon populations in areas of good habitat near Cochrane, Ontario, could sustain a long-term yield of 0.20-0.28 kg ha^{-1}, if young fish were harvested. On one fishery that had undergone past exploitation, the fishery collapsed very rapidly under this quota (Payne 1987).

In Lake Winnebago, Wisconsin, a strictly controlled winter spear fishery has maintained a 30 year average yield of 0.23 kg ha^{-1} (Folz and Meyers 1985). The fishery was not harvested above this level prior to the 30 year period. This represents an exploitation rate of about 2.5% of the population. Threader and Brousseau (1986) have indicated that the lake sturgeon in the Moose River, Ontario, can withstand an exploitation rate of 1.8% of the population.

The above examples illustrate that the sustainable yield of lake sturgeon is extremely low. Virgin populations in good habitat may sustain yields of 0.2 kg ha^{-1}, or a harvest level of about 2%. On water bodies where these levels have been exceeded, yields would be much less and may never recover unless exploitation is halted for long periods.

HABITAT

Habitat changes have also affected sturgeon populations across Ontario. Dam construction and mill effluents have had a serious impact on spawning, hatching and survival of several lake sturgeon populations (Harkness and Dymond 1961). Dam construction on large northern Ontario rivers has isolated several sturgeon populations between major power dams. In some reaches, sturgeon have maintained themselves, whereas in others, they have been extirpated. On the Groundhog River, where spawning areas are not influenced by man-induced water level fluctuations, populations have remained relatively high. On the Mattagami River, low water levels at the time of spawning have probably been a major factor in limiting recruitment and, in some reaches, the

lake sturgeon has disappeared. On the Frederick House River, a flow regime which maintains high flows during the spawning period has resulted in good recruitment. In areas of controlled water levels, the lake sturgeon spawning cycle must be considered if populations are to be maintained.

PROGNOSIS

The two major factors limiting lake sturgeon production are the biology of the species itself and its habitat requirements. Lake sturgeon are slow growing, late maturing (15-25 years) and spawn intermittently (once every 4-7 years). Consequently, the species has a slow turnover rate. Under current regulations, commercial fisheries remove most of the brood stock in a very short period. The fishermen then catch mainly young, small and immature fish (but still above the minimum legal size). Harvest exceeds recruitment and the standing stock is removed until the fishery eventually collapses. Following this, long-term yields of 0.01 kg ha^{-1} are maintained in some fisheries, indicating remnant populations, or small spawning populations that have eluded capture and which contribute to recruitment at a very low rate.

All lake sturgeon populations in Ontario that have been impacted by exploitation have declined to very low levels and have not recovered. The present commercial harvest in Ontario is <0.01% of the maximum obtained in 1895. Since 1964, the commercial harvest has declined from 45,250 kg to 7,940 kg in 1984. Also in 1984, the estimated angler harvest surpassed the commercial harvest for the first time and angler interest is increasing. Today's harvest comes primarily from northern inland waters with a small residual harvest from the Great Lakes, particularly Lake Huron.

Present regulations are not adequate to protect the few remaining fisheries, or to rebuild those that have been depleted. The harvest of lake sturgeon must be completely curtailed in those water bodies where they have declined. Innovative regulations designed to protect the brood stock are needed to maintain the remaining viable populations. Water level agreements should be established in critical areas to protect lake sturgeon habitat. If the above measures are not instituted in the near future, the lake sturgeon harvest in Ontario will become insignificant in the next 20 years.

ACKNOWLEDGEMENTS

I would like to thank the Ministry of Natural Resources staff who provided me with the information on the status of the lake sturgeon in their respective districts.

REFERENCES

CUSSON, M. R. 1955. King of fishes and fish of kings. Ont. Dep. Lands Forests, Kapuskasing Dist. Ms Rep. 8 p.

FOLZ, D. J., and L. S. MEYERS. 1985. Management of the lake sturgeon, *Acipenser fulvescens*, populations in the Lake Winnebago system, Wisconsin. Wis. Dep. Nat. Resour. Tech. Bull. 12 p.

HARKNESS, W. J., and J. R. DYMOND. 1961. The lake sturgeon. Ont. Dep. Lands Forests, Fish Wildl. Br., Toronto. 121 p.

HOUSTON, J. J. 1984. Status of the lake sturgeon (*Acipenser fulvescens*) in Canada. COSEWIC Rep., Scarborough, Ont. 44 p.

MacRITCHIE, I. 1983. Rationale and recommended sturgeon quotas for large rivers in the Cochrane District of the Ontario Ministry of Natural Resources. Ont. Min. Nat. Resour., Cochrane Dist. Ms Rep. 14 p.

NOWAK, A. M., and C. S. JESSOP. 1987. Biology and management of the lake sturgeon (*Acipenser fulvescens*) in the Groundhog and Mattagami rivers, Ontario, p. 20-32. *In* C.H. Olver [ed.] Proceedings of a workshop on the lake sturgeon (*Acipenser fulvescens*). Ont. Fish. Tech. Rep. Ser. No. 23. 99 p.

PAYNE, D. A. 1987. Biology and population dynamics of lake sturgeon (*Acipenser fulvescens*) from the Frederick House, Abitibi and Mattagami rivers, Ontario, p. 10-19. *In* C. H. Olver [ed.] Proceedings of a workshop on the lake sturgeon (*Acipenser fulvescens*). Ont. Fish. Tech. Rep. Ser. No. 23. 99 p.

SCOTT, W. B., and E. J. CROSSMAN. 1973. Freshwater fishes of Canada. Fish. Res. Board Can. Bull. 184. 966 p.

THREADER, R. W., and C. S. BROUSSEAU. 1986. Biology and management of the lake sturgeon in the Moose River, Ontario. North Am. J. Fish. Manage. 6:383-390.

YOUNG, J. K., and G. F. LOVE. 1970. The lake sturgeon (*Acipenser fulvescens*) of Lake Nipissing. Ont. Dep. Lands Forests, North Bay Dist. Ms Rep. 24 p.

BIOLOGY AND POPULATION DYNAMICS OF LAKE STURGEON (*ACIPENSER FULVESCENS*) FROM THE FREDERICK HOUSE, ABITIBI AND MATTAGAMI RIVERS, ONTARIO

D. A. Payne
Ontario Ministry of Natural Resources, P.O. Box 730, Cochrane, Ontario P0L 1C0

Data are presented on lake sturgeon (*Acipenser fulvescens*) stocks from the Frederick House, Abitibi and Mattagami rivers in the Cochrane District of Ontario. Information on population size, biological characteristics and production estimates are provided. Mean ages and lengths were significantly less for Mattagami River sturgeon than for sturgeon from the Abitibi and Frederick House rivers and mean weights were significantly less than for sturgeon from the Frederick House River. Growth rates were faster and relative biomass estimates were lower from the Mattagami River study areas. In general, sturgeon populations from the Frederick House and Abitibi rivers appear to be robust, while Mattagami River sturgeon have been reduced to essentially a young population with few adult fish remaining. Commercial overharvest and water level fluctuations may have caused the observed differences. As a result of the existing data, recommendations have been made to eliminate commercial fishing for sturgeon on the Mattagami River and to adjust quotas and conditions for commercial licences on the Abitibi River. It is also recommended that sturgeon in the Frederick House River be allocated exclusively to the sport fishery.

INTRODUCTION

Lake sturgeon (*Acipenser fulvescens*) are known to inhabit three large river systems in the Ontario Ministry of Natural Resources (OMNR) Cochrane District; the Abitibi, Mattagami and Frederick House (Fig. 1). A three year project was initiated on the Frederick House River (Fig. 2) in 1981, as part of a study to determine a productivity estimator for large rivers in northern Ontario (MacRitchie 1983a; Nowak and MacRitchie 1984). Although the study was not directly aimed at sturgeon, population and biomass estimates for sturgeon from a 14 km (98 ha) length of the Frederick House River from Neeland's Rapids to Carter's Rapids were obtained. Subsequent commercial quotas from a variety of reaches on the Abitibi and Mattagami rivers were based on this study (MacRitchie 1983b). Prior to quotas, one licence had been issued to fish sturgeon with 300 baited hook lines from Long Sioux Rapids to Fraserdale on the Abitibi River (Fig. 3) and from Sandy Falls to Poplar Rapids on the Mattagami River (Fig. 4) (Saunders 1981). A short portion of the Frederick House River from Flood's Landing to the Abitibi River is included in a licence for the Abitibi River.

In 1984, funding was obtained through the Canada Fisheries Industrial Development Program (FID) to carry out a project (see Gibson et al. 1985) on the Abitibi River between Island Falls and Abitibi Canyon Dam (Fig. 3). In addition to examining the biological characteristics of the sturgeon population, this study estimated population size, biomass and production of sturgeon in a 39.6 km (1,002 ha) reach of river.

A similar survey in 1985, again funded by FID, was undertaken on two stretches of the Mattagami River. The majority of the fishing effort was concentrated on a 33.5 km reach between Sturgeon Falls and Loon Rapids. Netting also took place between Island Falls and Smooth Rock Falls, a distance of 9.0 km (Fig. 3).

METHODS

In all three projects, sturgeon were captured using trap nets and/or gill nets. Biological characteristics were recorded and the fish were tagged using streamer tags affixed with surgical wire or monofilament line (Frederick House and Abitibi rivers), or metal jaw tags (Mattagami River). In all

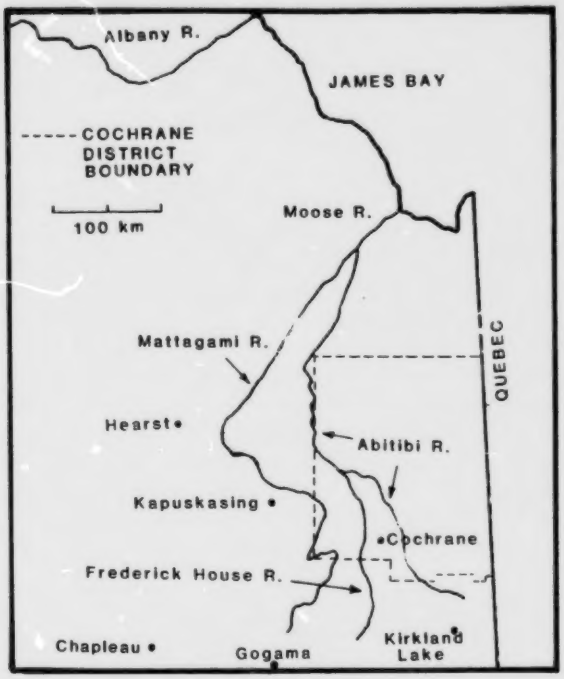

Fig. 1. Location of the Abitibi, Frederick House and Mattagami rivers to the Cochrane administrative district (OMNR).

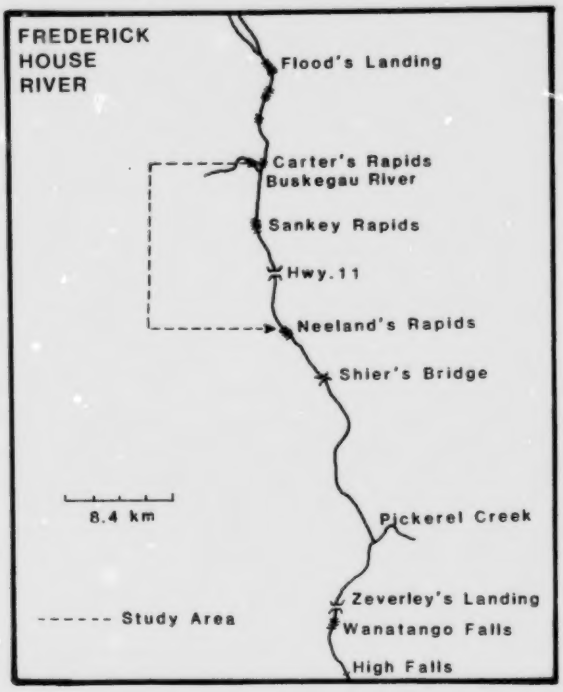

Fig. 2. Frederick House River study area.

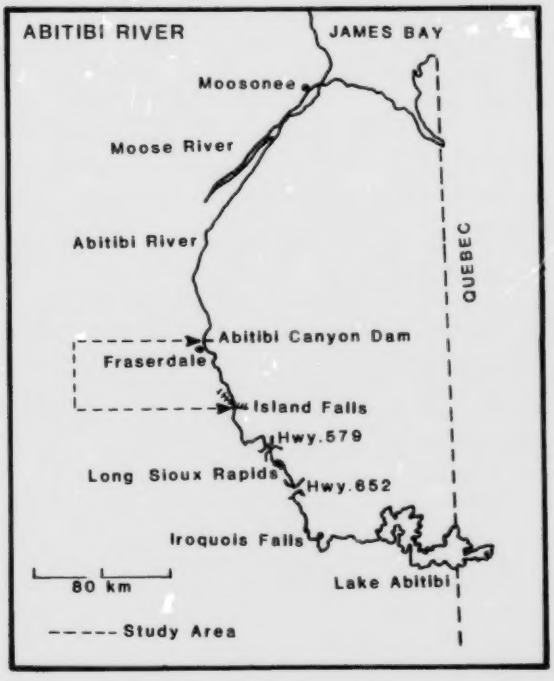

Fig. 3. Abitibi River study area.

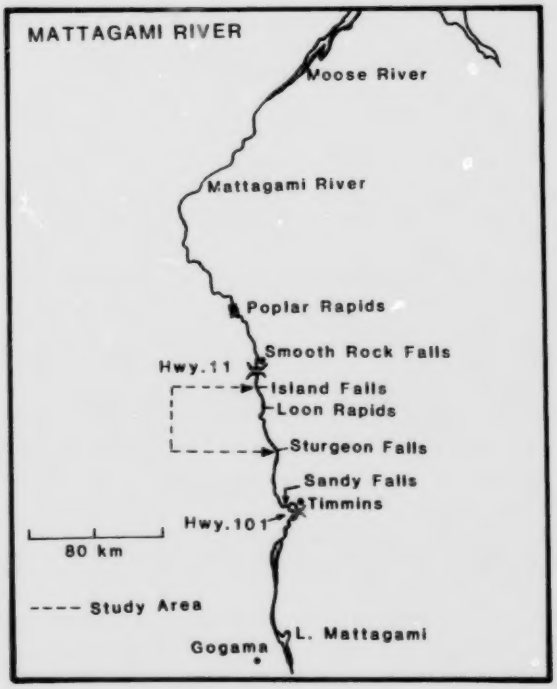

Fig. 4. Mattagami River study area.

cases, tags were attached to the leading edge of the dorsal fin. The first pectoral ray was removed for aging purposes. In most studies, netting took place between late May and mid-July. The exception to this was the reach of the Mattagami River from Island Falls to Smooth Rock Falls where sampling occurred from July to mid-August.

BIOLOGICAL CHARACTERISTICS

Growth rates, expressed as length-at-age and weight-at-age are given in Tables 1 and 2, respectively. Regressions for both length- and weight-at-age indicate that sturgeon from the Mattagami River grow faster than fish from both the Frederick House and Abitibi rivers. The difference in growth rates between the Abitibi and Frederick House rivers is much less pronounced, but suggests that Frederick House River sturgeon grow faster than stocks from the Abitibi River.

Mean weight, length and ages of captured sturgeon are shown in Table 3. Considerable variation is apparent among the three stocks. Frederick House River sturgeon have the greatest mean weights followed by the Abitibi and Mattagami stocks. Significant differences ($p < .05$) in mean weights of the fish occurred between the Frederick House River and both the Mattagami ($t = 3.00$, $df = 98$) and Abitibi ($t = 4.46$, $df = 425$) rivers. There was no significant difference ($p < .05$) between the mean weight of Mattagami River sturgeon and Abitibi River sturgeon ($t = 0.14$, $df = 477$).

Significant differences ($p < .01$) in mean lengths of sturgeon occurred among all three rivers. The Frederick House River sturgeon population had the largest mean lengths, followed again by fish from the Abitibi River ($t = 6.16$, $df = 415$) and the Mattagami River ($t = 6.10$, $df = 100$). The Abitibi River and Mattagami River sturgeon also exhibited a significant difference in mean lengths ($t = 7.68$, $df = 467$).

The mean ages of sturgeon showed less variation than weights and lengths. Abitibi River sturgeon had the oldest mean age. Frederick House River followed with slightly younger fish, however, no significant difference ($p < .05$) was observed ($t = 1.26$, $df = 223$). The mean age of Mattagami River sturgeon was significantly lower ($p < .01$) than both the Abitibi River ($t = 21.75$, $df = 272$) and Frederick House River ($t = 11.40$, $df = 85$) sturgeon.

In the previous determinations, data from both stretches of the Mattagami River were combined. Tests of significance showed no difference ($p < .05$) between mean lengths ($t = .032$, $df = 72$), weights ($t = 1.93$, $df = 77$) and ages ($t = 1.13$, $df = 72$) of sturgeon between the study areas. In addition, data from the 1982 Frederick House River study were used to compare biological characteristics between rivers, since complete raw data were not available for the 1981 and 1983 studies.

POPULATION DYNAMICS

In 1981 and 1983, population estimates were calculated using an adjusted Peterson estimate (Ricker 1975) for a 14 km (98 ha) stretch below Neeland's Rapids extending to Carter's Rapids on the Frederick House River (MacRitchie 1983a; Nowak and MacRitchie 1984). The population estimate was 125 fish in 1981, and 186 fish in 1983 (Table 4). This represented a total biomass in the 98 ha section of 1,318.5 kg (13.5 kg ha^{-1}) and 2,183.6 kg (22.3 kg ha^{-1}), respectively. Since fishing effort was limited to Neeland's Rapids, these estimates are conservative and reflect the spawning population.

A Schnabel population estimate (Ricker 1975) of 994 sturgeon (Table 4) was obtained from Island Falls to Abitibi Canyon Dam on the Abitibi River in 1984 (Gibson et al. 1985). A total biomass of 7,082.6 kg of sturgeon in the 1,002 ha reach provided a relative biomass of 7.1 kg ha^{-1}.

Two stretches of the Mattagami River were studied in 1985 (Table 4). The upper reach from Sturgeon Falls to Loon Rapids had an estimated 114 sturgeon with a total and relative biomass of 775.8 kg and 2.0 kg ha^{-1}, respectively. Only 33 sturgeon were estimated in the lower reach from Island Falls to Smooth Rock Ralls. The total

Table 1. Length-at-age relationships of lake sturgeon from selected reaches of the Frederick House, Abitibi and Mattagami rivers.

River	Location	Year	Fork length-at-age (cm)[a]
Frederick House	Neeland's Rapids to Carter's Rapids	1981	Length = 34.8 + 2.33 (age) N = 12
Frederick House	Neeland's Rapids to Carter's Rapids	1982	Length = 67.7 + 1.26 (age) N = 13
Frederick House	Neeland's Rapids to Carter's Rapids	1983	Length = 59.5 + 1.54 (age) N = 15
Frederick House	Neeland's Rapids to Carter's Rapids	1981-1983	Length = 52.8 + 1.71 (age) N = 40
Abitibi	Island Falls to Abitibi Canyon Dam	1984	Length = 57.6 + 0.99 (age) N = 110
Mattagami	Sturgeon Falls to Loon Rapids	1985	Length = 44.4 + 3.43 (age) N = 55
Mattagami	Island Falls to Smooth Rock Falls	1985	Length = 46.6 + 3.74 (age) N = 19
Mattagami	Sturgeon Falls to Smooth Rock Falls	1985	Length = 46.0 + 3.40 (age) N = 74

[a]All regression lines are significant at $p < .05$.

Table 2. Weight-at-age relationships of lake sturgeon from selected reaches of the Frederick House, Abitibi and Mattagami rivers.

River	Location	Year	Weight-at-age (g)[a]
Frederick House	Neeland's Rapids to Carter's Rapids	1981	Wt = -5.90e + 03 + 5.14e + 02 (age) N = 13
Frederick House	Neeland's Rapids to Carter's Rapids	1982	Wt = -3.70e + 03 + 4.33e + 02 (age) N = 12
Frederick House	Neeland's Rapids to Carter's Rapids	1983	Wt = -4.14e + 03 + 4.94e + 02 (age) N = 15
Frederick House	Neeland's Rapids to Carter's Rapids	1981-1983	Wt = -4.81e + 03 + 4.88e + 02 (age) N = 40
Abitibi	Island Falls to Abitibi Canyon Dam	1984	Wt = -3.29e + 03 + 2.79e + 02 (age) N = 110
Mattagami	Sturgeon Falls to Smooth Rock Falls	1985	Wt = -3.36e + 03 + 9.39e + 02 (age) N = 55
Mattagami	Island Falls to Smooth Rock Falls	1985	Wt = -2.89e + 03 + 9.42e + 02 (age) N = 19
Mattagami	Sturgeon Falls to Smooth Rock Falls	1985	Wt = -3.17e + 03 + 9.34e + 02 (age) N = 74

[a]All regression lines are significant at $p < .05$.

NOTE: In all relationships Xe + 03 = X x 10^3.

Table 3. Biological characteristics of captured lake sturgeon from selected reaches of the Frederick House, Abitibi and Mattagami rivers.

River	Location	Year	Sample size	Mean fork length (cm)	Mean weight (g)	Mean age (yrs)
Frederick House	Neeland's Rapids to Carter's Rapids	1981	Unknown	111.6[a]	10,548.0	34.3[b]
Frederick House	Neeland's Rapids to Carter's Rapids	1982	25	109.8	10,402.2	34.0
Frederick House	Neeland's Rapids to Carter's Rapids	1983	Unknown	113.9[a]	11,739.8	34.5[b]
Abitibi	Island Falls to Abitibi Canyon Dam	1984	392	94.5	7,125.4	36.4
Mattagami	Sturgeon Falls to Loon Rapids	1985	57	81.6	6,305.7	10.9
Mattagami	Island Falls to Smooth Rock Falls	1985	20	79.9	5,468.6	8.8

[a]Mean length: Estimate was obtained from length-weight relationship using combined data from 3 year study.
[b]Mean age: Estimate was obtained from instantaneous growth rates using combined data from 3 year study.

Table 4. Population and biomass estimates of lake sturgeon from selected reaches of the Frederick House, Abitibi and Mattagami rivers.

River	Location	Year	Population estimate	Confidence interval ($p < .05$)	Total biomass (kg)	Area (ha)	Relative biomass (kg ha^{-1})
Frederick House	Neeland's Rapids to Carter's Rapids	1981	125	46-311	1,318.5	98	13.5
Frederick House	Neeland's Rapids to Carter's Rapids	1983	186	Unknown	2,183.6	98	22.3
Abitibi	Island Falls to Abitibi Canyon Dam	1984	994	830-1,213	7,082.6	1,002	7.1
Mattagami	Sturgeon Falls to Loon Rapids	1985	114	74-182	775.8	396	2.0
Mattagami	Island Falls to Smooth Rock Falls	1985	33	16-72	180.5	189	1.0

biomass of 180.5 kg represented a relative biomass of 1.0 kg ha^{-1}. Both population estimates were calculated using the Schnabel method (Ricker 1975).

Biomass production estimates were calculated for the Frederick House River (1981 and 1983), the Abitibi River and two reaches of the Mattagami River (Table 5). Considerable variation occurred in production, both between years (Frederick House River) and study areas. Production in kg $ha^{-1}yr^{-1}$ ranged from 0.165 on the Mattagami River to 0.937 on the Frederick House River. The two reaches of the Mattagami River were reasonably consistent at 0.270 between Sturgeon Falls and Loon Rapids and 0.165 between Island Falls and Smooth Rock Falls.

Information regarding the proportion of total fish biomass attributable to lake sturgeon alone is available for the Frederick House River only. Nowak and MacRitchie (1984) reported that sturgeon comprised a major portion of the biomass of all fish species caught at 36 and 71% by weight for 1981 and 1983, respectively. High water levels in 1983 made capture of fish other than sturgeon difficult. This may account for the large increase in biomass apportioned to sturgeon (C.S. Brousseau, OMNR, Cochrane, Ont. POL 1CO, pers. comm.).

DISCUSSION

It is apparent from this summary that differences occur between the sturgeon populations from the study areas. Biological characteristics (growth rates, mean lengths, weights and ages) differ significantly and data presented on relative biomass and production provide further support for this observation.

Many factors may contribute to these differences. Water levels and discharge are known to fluctuate to varying degrees in all three rivers as a result of hydro control dams. Environment Canada (1983a) records indicate that from May to June, mean water discharge (m^3 sec^{-1}) drops from 332 to 169 at Smooth Rock Falls on the Mattagami River, from 675 to 396 at Abitibi Canyon

Table 5. Biomass production estimates for lake sturgeon from selected reaches of the Frederick House, Abitibi and Mattagami rivers.

River	Location	Year	Growth[a] (avg. kg $fish^{-1}yr^{-1}$)	Population estimate	Biomass production (kg yr^{-1})	Area (ha)	Production (kg ha^{-1} yr^{-1})
Frederick House	Neeland's Rapids to Carter's Rapids	1981	0.514	125	64.3	98	0.656
Frederick House	Neeland's Rapids to Carter's Rapids	1983	0.494	186	91.9	98	0.937
Abitibi	Island Falls to Abitibi Canyon Dam	1984	0.279	944	263.4	1002	0.263
Mattagami	Sturgeon Falls to Loon Rapids	1985	0.939	114	107.0	396	0.270
Mattagami	Island Falls to Smooth Rock Falls	1985	0.942	33	31.1	189	0.165

[a]Growth taken as slope of the regression line from weight-at-age relationships.

on the Abitibi River and from 55.6 to 39.7 at the Frederick House Lake Dam on the Frederick House River. These values are mean monthly discharges taken over a 62, 53 and 44 year period, respectively.

It is difficult to judge the effect the reduction in water levels may have. Data from the Frederick House River (Nowak and MacRitchie 1984) and the Abitibi River (Gibson et al. 1985) suggest that spawning still occurs in the study areas on these rivers during the discharge reduction periods, but not on the Mattagami River (OMNR, unpubl. data). Limited data are available on the possible effects on recruitment. Nowak and MacRitchie (1984) calculated a critical minimum discharge for the Frederick House River of 10 to 12 m^3sec^{-1}. Flow regimes during the spawning and early life stages of the lake sturgeon appear to satisfy this minimum requirement. However, in May and June the authors did note potential spawning and nursery areas high above the water line.

Observations on the Mattagami River also indicate that sturgeon abundance was influenced by the creation of water control dams. Prior to construction of the Lower Sturgeon Generating Station at Sturgeon Falls, a lightly exploited population of lake sturgeon was known to inhabit the area located above this point to Sandy Falls near Timmins, Ontario (C. S. Brousseau, OMNR, pers. comm.). It now appears as though a collapse of this stock has occurred, possibly due to a change in water level caused by the control dam. Environment Canada (1983b, 1984) surface water data shows a rapid increase in discharge beginning in late April and continuing through until mid-June, at which time discharge returns to approximately its early April value. This wide fluctuation is in place to control water levels in the city of Timmins and to generate hydroelectric power.

In all likelihood, hydroelectric and water control dams do have an effect on lake sturgeon in the study areas. This has been well documented in other areas for *Acipenser* spp. (Harkness and Dymond 1961; Priegel and Wirth 1971; Priegel 1973; Murawski and Pacheco 1977; Votinov and Kas'yanov 1978). The magnitude and severity of this effect may be site dependent and would have to be studied further to determine specific effects.

Exploitation of lake sturgeon is a second stress that may account for the observed differences in biological characteristics and population dynamics in the study areas. Commercial fishing records for the Mattagami River date back as far as 1917 (Saunders 1981) and Fig. 5 shows landings of this species from 1927 to 1985. In 1984, a commercial quota system was implemented on a reach specific basis. This replaced a licence that allowed 300 baited hooks in the area between Sandy Falls and Poplar Rapids. The quotas in the study areas were dependent on destination of the catch. For domestic markets, 0.20 kg $ha^{-1}yr^{-1}$ was set, and for export to the U.S., 0.28 kg $ha^{-1}yr^{-1}$ was allowed (MacRitchie 1983b). The differences are related to mercury contamination levels and the size of fish that would meet the minimum accepted standards. At the present time, the recommended quota of sturgeon is 225 kg from Sturgeon Falls to Loon Rapids and 91 kg from Island Falls to Smooth Rock Falls.

Historically, commercial harvest from the Mattagami River fluctuated widely from a record high of 5,518 kg in 1948 to a low of 190 kg in 1967. The low levels of harvest continued after 1967. Since effort data are not available, it is unknown whether the decline in harvest is a result of overexploitation or reduced effort. Relative harvest (kg ha^{-1}) ranged from 0.06 to 1.63 with a mean of 0.64 kg ha^{-1} from 1927 to 1963. Based on MacRitchie's (1983b) recommendation of 0.28 kg $ha^{-1}yr^{-1}$, it would appear that severe overexploitation has occurred. Relative harvest was applied to the entire 130 km (3,380 ha) of river that was under licence, since no information was available to indicate precise harvest locations. The estimate of present production from the study areas (Table 5) indicates that the recommended quotas of 0.20 and 0.28 kg $ha^{-1}yr^{-1}$ allow overexploitation of sturgeon in the Mattagami River. The observed growth rates in these areas may be a density dependent response to low population levels.

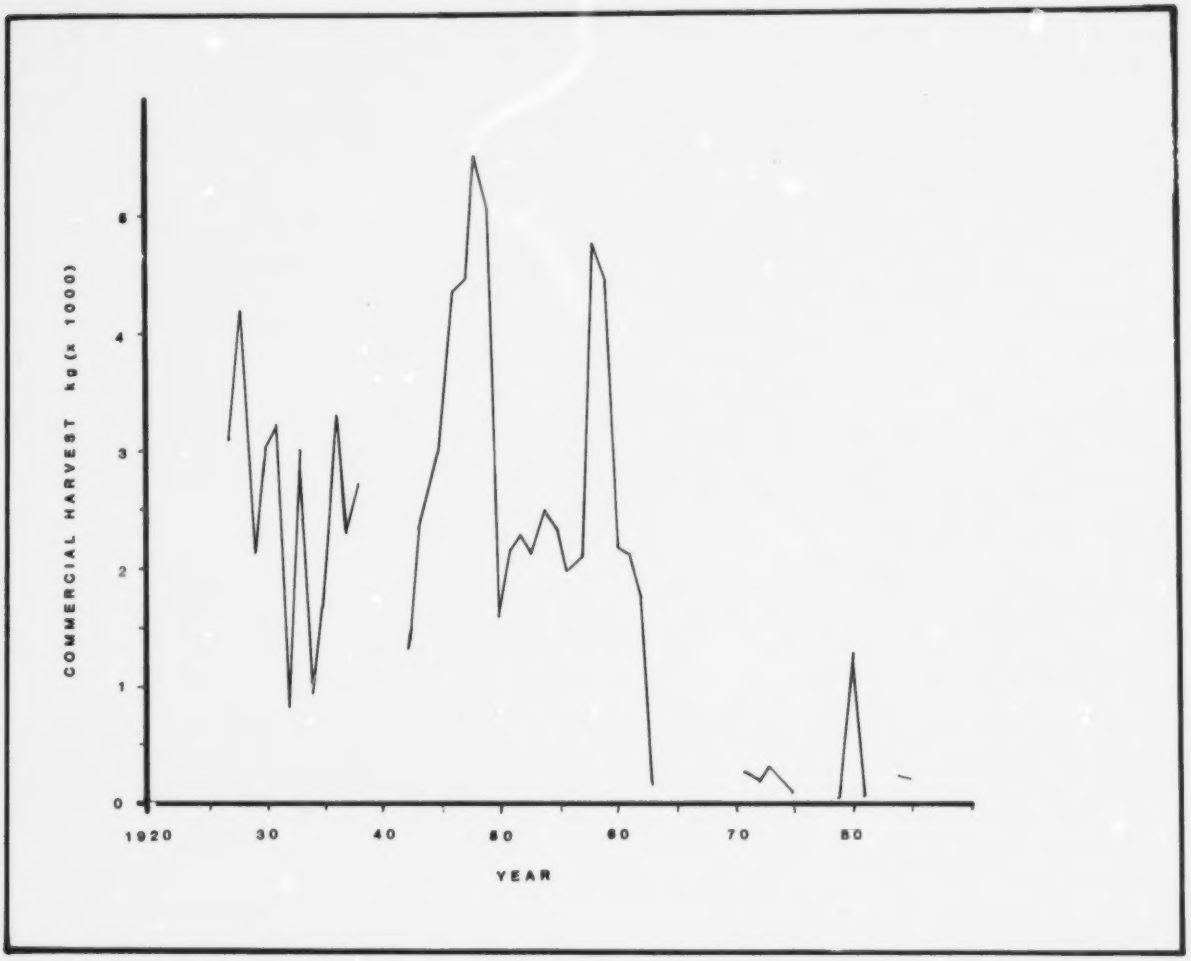

Fig. 5. Mattagami River sturgeon harvest, 1927-1985.

The Abitibi River has also been fished commercially for lake sturgeon. Records from Fisheries Branch (OMNR, unpubl. data) dating from 1935 show a range from a high of 2,414 kg in 1936 to a low of 3.6 kg in 1978. Under current restrictions, a quota of 280 kg is permitted from the study area.

Generally, harvest of sturgeon from the Abitibi River has been considerably less than that from the Mattagami River. Over a period of 47 years (1935-82) mean harvest has been 527 kg yr^{-1} or 0.21 kg $ha^{-1}yr^{-1}$. This corresponds favourably to MacRitchie's (1983b) recommendations and yearly production (Table 5) approximates the allowable commercial harvest.

In MacRitchie's (1983b) consideration of an appropriate quota for northeastern Ontario rivers, sturgeon between 55 and 115 cm (FL) were identified as accounting for a production of 0.28 kg $ha^{-1}yr^{-1}$. The upper limit of 115 cm (FL) satisfied the requirement for a mercury level of 1.0 mg L^{-1} or less for export to United States markets. MacRitchie (1983b) further indicated that a maximum size of 90 cm (FL) would protect the majority of the adult spawning sturgeon. The study conducted by Gibson et al. (1985) on a reach of the Abitibi River estimated production of sturgeon between 55 and 90 cm (FL) at 0.155 kg $ha^{-1}yr^{-1}$. This represents an allowable quota of 155 kg yr^{-1} in the 1002 ha study area, with a maximum size limit of 90 cm (FL).

Sport fishing for lake sturgeon has received little attention to date, and as a result limited information is

available. Casual observations made by fish and wildlife staff from the Cochrane District and Northern Region (OMNR) suggest the popularity of sturgeon fishing is increasing, especially on the Frederick House River. Angling seems to be best for this species in June and, to a lesser extent, September. It is not uncommon now, in June, to see up to 20 anglers a day fishing the stretch between Zeverley's Landing and Highway 11 on the Frederick House River (Fig. 2). Most parties would have at least one sturgeon (P. Dennis, OMNR, Cochrane, Ont. P0L 1C0, pers. comm.). One particularly zealous fisherman reported catching over 60 sturgeon in 1985, with the largest fish weighing approximately 20 kg. The majority of these fish were returned to the water.

At the present time, sport fishing is not considered to be a major stress on lake sturgeon in the Frederick House, Abitibi and Mattagami rivers. However, as their popularity as a game fish increases, this situation may change. Closer monitoring will be required.

A further parameter influencing sturgeon populations is water quality (Harkness and Dymond 1961; Klyashtorin 1976). Large river inventories have been conducted on the Frederick House and Mattagmi rivers and basic parameters such as dissolved oxygen, alkalinity, dissolved solids and pH appear to be typical for this area and should not be a major limiting factor for sturgeon.

In the early 1920s, the hydroelectric dam at Sturgeon Falls commenced operation and since that time, log drives on the Mattagami River to the pulp and paper mill at Smooth Rock Falls have been common. Bark and wood fibre settling to the river bed over the years could influence production of invertebrates, a major food source of sturgeon.

CONCLUSIONS AND RECOMMENDATIONS

Although precise conclusions cannot be drawn, the accumulative effects of exploitation and water level fluctuations may account for the observed differences in sturgeon populations from the study areas. The data suggests that robust populations of sturgeon occur in the study areas of the Frederick House and Abitibi rivers. Conversely, only a limited brood stock of sturgeon remains in the study area of the Mattagami River where high levels of exploitation have been documented.

In order to protect and ensure a continued sturgeon resource in the Cochrane District, the following measures are recommended: cancellation of the existing commercial licences on the Mattagami River; a maximum size limit of 90 cm (FL) for all commercially harvested sturgeon; reduction of the sturgeon quota on the study reach of the Abitibi River to 155 kg to reflect production under 90 cm; and allocation of sturgeon in the Frederick House River exclusively to the sport fishery.

ACKNOWLEDGEMENTS

I wish to thank Chris Brousseau, Northern Region, for his comments and suggestions throughout the preparation of this report.

REFERENCES

ENVIRONMENT CANADA. 1983a. Historical stream flow summary, Ontario, to 1982. Inland Waters Directorate, Water Resources Branch, Water Survey of Canada, Ottawa. 523 p.

ENVIRONMENT CANADA. 1983b. Surface water data, Ontario, 1982. Inland Waters Directorate, Water Resources Branch, Water Survey of Canada, Ottawa. 279 p.

ENVIRONMENT CANADA. 1984. Surface water data, Ontario, 1983. Inland Waters Directorate, Water Resources Branch, Water Survey of Canada, Ottawa. 279 p.

GIBSON, D. W., E. R. ARMSTRONG, and S. AUBRY. 1985. Age, growth and management of lake sturgeon (*Acipenser fulvescens*) from a reach of the Abitibi River. Ont. Min. Nat. Resour., Cochrane Dist. Ms Rep. 38 p.

HARKNESS, W. J. K., and J. R. DYMOND. 1961. The lake sturgeon. Ont. Dep. Lands Forests, Fish Wildl. Br., Toronto. 121 p.

KLYASHTORIN, L. B. 1976. The sensitivity of young sturgeons to oxygen deficiency. J. Ichthyol. (Engl. Transl. Vopr. Ikhtiol.) 16:677-681.

MacRITCHIE, I. 1983a. Towards a river fish productivity estimator; the Frederick House River experience. Ont. Min. Nat. Resour., Cochrane Dist. Ms Rep. 43 p.

MacRITCHIE, I. 1983b. Rationale and recommended sturgeon quotas for large rivers in the Cochrane District of the Ontario Ministry of Natural Resources. Ont. Min. Nat. Resour., Cochrane Dist. Ms Rep. 14 p.

MURAWSKI, S. A., and A. L. PACHECO. 1977. Biological and fisheries data on Atlantic sturgeon, *Acipenser oxyrhynchus* (Mitchill). Natl. Mar. Fish. Serv. Tech. Ser. Rep. No. 10. 69 p.

NOWAK, A., and I. MacRITCHIE. 1984. A study of the Frederick House River, Cochrane District, 1981-1983. Ont. Min. Nat. Resour., Cochrane Dist. Ms Rep. 99 p.

PRIEGEL, G. R. 1973. Lake sturgeon management on the Menominee River. Wis. Dep. Nat. Resour. Tech. Bull. 67. 20 p.

PRIEGEL, G. R., and T. L. WIRTH. 1971. The lake sturgeon, its life history, ecology and management. Wis. Dep. Nat. Resour. Publ. 240-70. 16 p.

SAUNDERS, D. A. 1981. Recommendations on the Mattagami River sturgeon fishery. Ont. Min. Nat. Resour., Cochrane Dist. Ms Rep. 16 p.

RICKER, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191. 382 p.

VOTINOV, N. P., and V. P. KAS'YANOV. 1978. The ecology and reproductive efficiency of the siberian sturgeon, *Acipenser baeri*, in the Ob as affected by hydraulic engineering works. J. Ichthyol. (Engl. Transl. Vopr. Ikhtiol.) 18:20-28.

BIOLOGY AND MANAGEMENT OF THE LAKE STURGEON (*ACIPENSER FULVESCENS*) IN THE GROUNDHOG AND MATTAGAMI RIVERS, ONTARIO

A. M. Nowak
R.R. 3, Cochrane, Ontario P0L 1C0

C. S. Jessop
Ontario Ministry of Natural Resources, 6-8-10 Government Road, Kapuskasing, Ontario P5N 2W4

A study was conducted on the lake sturgeon (*Acipenser fulvescens*) fishery of the Groundhog and Mattagami rivers from 1982 to 1984. The population was estimated at 8429 fish with a corresponding annual production of 4648 kg yr^{-1} (3.97 kg $ha^{-1}yr^{-1}$). The growth rate of sturgeon in the Groundhog River was much faster than that determined for other northern waters. Ages ranged from 9 to 49 years with earliest observed ages of maturity for males at 19 years and for females at 22 years. Movements of up to 26 km were recorded. Mean concentrations of mercury in fish from the Groundhog River were 0.11 ppm and 0.17 ppm in fish from the Mattagami River. Analysis of creel survey data revealed that angler harvest equals or exceeds production at the present exploitation rate of 5%. The fishery appears to be operating on the threshold of overexploitation, precluding the opportunity for a commercial harvest. Options for managing the sport fishery include a fish sanctuary, a slot size limit and limited entry.

INTRODUCTION

Several studies have examined the life history and harvest of the lake sturgeon (*Acipenser fulvescens*) in Quebec and northern Ontario where they are resident in some large water bodies and river systems. Lake sturgeon occur in the Groundhog, Mattagami and Missinaibi rivers and several of their tributaries in the Ontario Ministry of Natural Resources (OMNR) Kapuskasing District.

The lower Groundhog River has been subject to increasingly heavy angler pressure over the past 10 years (E.H. Lucking, OMNR, Timmins, Ont. P4N 3W2, pers. comm.) with lake sturgeon and walleye (*Stizostedion vitreum vitreum*) being the two main species sought. This section of river formerly supported a commercial fishery for sturgeon which was closed in 1971 due to infractions of the Ontario Fishery Regulations. At that time it was also observed that the mean length of captured fish was less than the legal limit, indicating overexploitation of the fishery. Lawson (1983) observed that the angler harvest in 1982 was greater than the previous commercial harvest. Presently, there is renewed interest in opening the commercial sturgeon fishery on the lower Groundhog River.

A three year study of the sturgeon population in part of the Groundhog and the Mattagami rivers was conducted from 1982 to 1984. The study was funded through the Canada Fisheries Industrial Development Program (F.I.D.). Lawson (1983) reported the results of the 1982 program and Nowak (1984) prepared a report on the 1983 and 1984 study. The purpose of the present report is to: (1) summarize the results of these studies including population, production and biomass estimates; (2) relate production to present harvest; (3) make recommendations with respect to the feasibility of a commercial fishery; and (4) determine if further regulation of the sport fishery is necessary.

THE STUDY AREA

The study area included the Groundhog River from LaDuke Rapids (a barrier to upstream movement) to its confluence with the Mattagami River and the Mattagami River from Cypress Falls (a barrier to upstream movement) to the

Kapuskasing River (Fig. 1). The Groundhog River from LaDuke Rapids to Whist Falls was not part of the study area in 1982. Total length of the sections of the rivers sampled was 44.6 km with a total surface area of 1168 ha. The study area was divided into six work fields and 15 work areas to simplify data recording for netting, creel survey and fish movements.

Water levels are controlled by Ontario Hydro's Little Long Dam on the Mattagami River some 30 km downstream from the confluence of the Kapuskasing River. Due to flooding, the Mattagami River within the study area no longer contains rapids. This section of the Mattagami River and the lower 2 km of the Groundhog River are actually backflooded reservoirs.

Annual mean discharge for the Groundhog River during the period of 1920 to 1982 was 145 m^3sec^{-1}. Mean monthly flows for the same period ranged from 51.7 m^3sec^{-1} in January to 522 $m^3 sec^{-1}$ in May (Environment Canada 1983).

The general topography of the surrounding land is gently rolling plains of clay and gravel till. The rivers have cut deeply into this bed of till and are punctuated by rapids where outcrops of Precambrian bedrock are exposed. Most of the surrounding area has been cut over to the 120 m reserve.

MATERIALS AND METHODS

During the 1983 field season, water samples for determining dissolved oxygen, pH, alkalinity and TDS were taken monthly at seven stations on the Groundhog River and six on the Mattagami River.

Gill nets were the primary method of capturing lake sturgeon. In 1982, gill nets with mesh sizes of 7.6, 10.2, 12.7 and 25.4 cm (stretched measure) were used. Mesh sizes used in 1983 were 3.8, 6.4, 15.2 and 25.4 cm. In 1984, mesh sizes used were 3.8, 6.4, 11.4, 17.8, 22.9 and 30.5 cm.

Netting effort was directed mainly toward securing large sample sizes rather than toward randomization of capture with respect to size range and location. In 1982, gillnetting activities were concentrated in work field 2 and 3C in order to obtain an increased sturgeon sample. In 1982, gill nets were checked approximately every hour, while in 1983 and 1984 net sets were from 6 to 24 hours in duration.

In 1982, two 1.8 m trap nets were also used and checked approximately every 24 hours. An electrofishing boat was also used for three days in 1982. Hook lines were used in 1984 to supplement the gill net catch, as they were less size selective and could be set in a variety of habitats.

Sturgeon were tagged using monel metal jaw tags inserted through the muscle tissue immediately anterior to the dorsal fin. Atkins disc tags were used on small fish (<40 cm).

Measurements taken included total length and fork length in 1982, total length and dressed length in 1983 and total length, dressed length and fork length in 1984. Weights were taken in all three years by means of a spring type scale. Fish were released immediately after sampling which resulted in some immediate recaptures in the same or nearby areas.

In the early stages of the study, pectoral fin rays were removed from some tagged sturgeon, but this practice was discontinued owing to stress on the fish. The fin rays were then only taken from angler-caught and sacrificed fish. Sturgeon were aged by counting annuli in the basal section of the first pectoral fin ray according to procedures outlined by Roussow (1957) and Dadswell (1979). Fin rays were removed by making an incision along the groove between the first ray as close to the point of articulation with the body wall as possible. The fin rays were dried and cross-sectioned using a small fine-toothed coping saw, cleaned in 95% ethanol and the growth rings counted through phase contrast microscopy enhanced with a blue filter. Fin ray sectioning and aging was done at OMNR regional fish and wildlife laboratories in Sault Ste. Marie in 1982 and in Cochrane in 1983 and 1984.

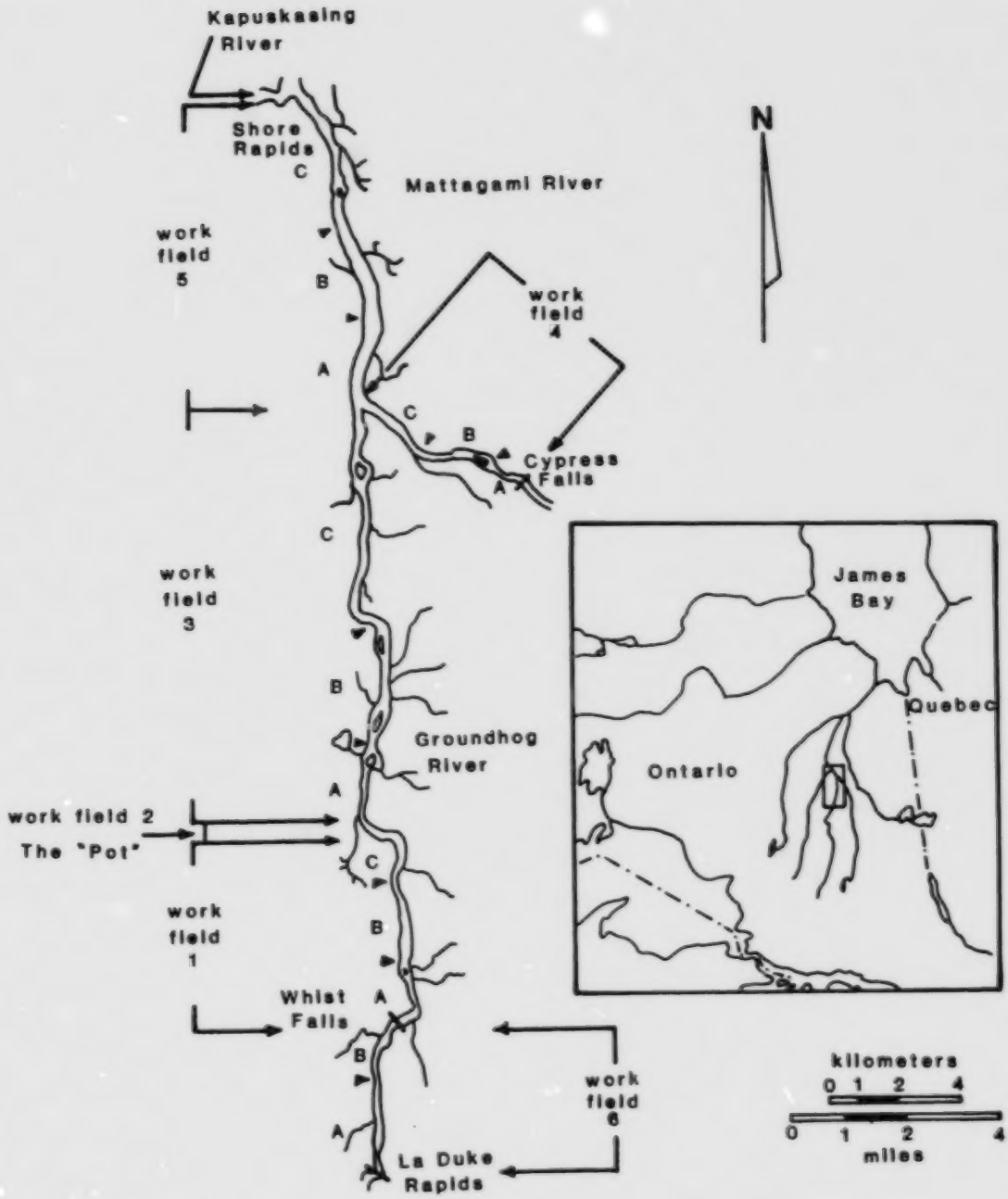

Fig. 1. General location and detail of the Groundhog and Mattagami River study area. Rivers flow north.

In order to obtain information on age at sexual maturity, gonad samples were collected from angler-caught sturgeon during late June and July. Gonad collection, preservation and interpretation methods were as outlined by Threader (1981). Testes were fixed in Bouin's fixative; ovaries were fixed in Helly's fluid. The gonadal tissue from both sexes was sectioned at 8 to 10 µm and stained using a haematoxylin/eosin stain. Females were judged to be immature, resting, active, regressing, ripe or spent, based on the developmental stage(s) of the oocytes. Males were classed as immature, inactive, ripe or spent depending on the presence, absence or a combination of spermatagonia, primary and secondary spermatocytes, spermatids and tailed and untailed spermatozoa (Huff 1975). Samples taken in 1984 have not been analyzed to date.

A minimum of 100 g of epaxial muscle was removed from 31 sacrificed sturgeon in 1976 and 20 in 1983 for mercury analysis by the Ontario Ministry of the Environment.

The creel survey was non-random and was carried out between approximately June 1 (sturgeon season opens on June 15) and August 31 each year. In 1984, it was supported by a daily boat count which was also non-random. Interview data were recorded on OMNR creel survey forms and summarized on a daily and monthly basis. Anglers were asked to contribute pectoral fin rays and gonads from the sturgeon they kept for age and maturity analysis.

Effort (angler-hours) and catch (fish kept) data were analysed by work field and month and weekend and weekday periods. Total estimated angler-hours per time period for each work field were multiplied by observed catch-per-unit-effort (CUE - estimated weight kept hr^{-1}) to determine harvest in kg for the period of June 15 to August 31. These figures were adjusted using a factor derived from boat count information in 1984. In that year, approximately 21% of the anglers counted were not interviewed. The harvest estimates were increased to reflect this unrecorded effort. In 1984, the estimated harvest was increased by 21% for each month. In 1983, the estimated harvest was increased using boat count data (interviewed/not interviewed) derived from July and August 1984. This procedure, while perhaps irregular, should compensate for unrecorded pressure during and after the study period.

RESULTS AND DISCUSSION

WATER CHEMISTRY

Water chemistry comparisons at seven stations on the Groundhog River and six stations on the Mattagami River indicated that the Groundhog River had higher mean readings for dissolved oxygen (7.1 mg L^{-1}), pH (7.8) and alkalinity (56.2 mg L^{-1}) than the Mattagami River which had mean values of 6.2 mg L^{-1}, 7.5 and 51.3 mg L^{-1} for oxygen, pH and alkalinity, respectively. Mean TDS readings were 77.9 mg L^{-1} for the Groundhog River and 89.4 mg L^{-1} for the Mattagami River. Water temperatures for both rivers were similar, ranging from 19 to 24°C between June and August 1983.

NETTING EFFORT

In 1982, a total of 1533 net-hours resulted in the capture of 246 lake sturgeon. A 1.8 m trap net was used for 1473 hours, but only caught 30 sturgeon. The large mesh gill net (25.4 cm) was the most effective gear as 198 sturgeon were caught in only 36 hours of effort. Six sturgeon were caught by angling and one by electrofishing.

In 1983, a total of 284 net-hours of effort resulted in 375 lake sturgeon being captured. As in 1982, effort was concentrated in areas of known, high fish density rather than randomly distributed.

Generally, very few young fish were caught, indicating a difference in spatial distribution between sturgeon less than and older than 20 years of age. Although a small mesh net was used for 107 hours, the mean fork length of fish captured was 103.0 cm, corresponding to an age of approximately 20 years. This differed very little from the means of 106.5 and 110.2 cm for the 15.2 and 25.4 cm mesh, respectively. Observations made on the Frederick House and Mattagami rivers in Cochrane Dis-

trict in 1982 and 1983 indicated that young fish tended to form nursery sub-populations, inhabiting different areas than sub-adult and mature fish (OMNR, unpubl. data). No such aggregations were located during this field study.

In 1984, 857 net-hours of effort captured 945 lake sturgeon. As in previous years, few young fish were caught. Again net location was not random. Most net sets used 17.8 cm and 22.9 cm mesh gill nets. Small mesh (3.8 to 10.0 cm) and 30.5 cm gill nets were used sparingly.

AGE AND GROWTH

Mean fork lengths-at-age from 257 sturgeon (Table 1) were plotted against age and a growth curve was fitted by eye (Fig. 2). As the curve indicates, there was a rapid increase in fork length up to about age 20, after which the rate of growth gradually decreased. There was, however, considerable scatter in points about the line, owing in part to the fact that lengths for males and females and for immature and ripe fish were combined in calculating the means.

Growth in length was relatively fast and more comparable to that found in Wisconsin (Priegel and Wirth 1978) and Lake St. Francis, Quebec (Currier and Roussow 1951), than to growth in other northern studies. Growth was almost twice as fast as that reported for the Moose River (Threader 1981).

Mean weight-at-age for the 257 sturgeon (Table 1) was also plotted against age and a weight-age curve fitted by eye (Fig. 3). Here again, the growth rate accelerated during the first 20-25 years, then decreased at greater ages.

The weight-length relation, based on a sample of 965 lake sturgeon was Ln (W) = 3.15 * Ln (L) - 5.45 where W is the weight in g and L the fork length in cm. The slope of the regression (3.15) indicates allometric growth of the lake sturgeon.

A sample of 752 fish netted in 1982 and 1983 had a mean weight of 11.38 kg, mean fork length of 107.6 cm, mean dressed length of 73.0 cm and mean condition factor of 0.85. Mean weight of angler-caught fish in 1982 and 1983 was slightly lower (10.12 kg). Differences in mean size appear to be due more to differences in spatial and temporal distribution of netting effort than to gear selectivity. No attempt

Table 1. Mean fork length-at-age and weight-at-age for sturgeon from the Groundhog and Mattagami rivers.

Age	Sample size (no.)	Mean fork length (cm)	Mean weight (g)
9	5	53.8	1440
10	1	71.5	2800
11	2	58.0	1650
12	3	78.0	3900
13	11	78.4	3654
14	3	82.8	4383
15	8	89.9	6328
16	3	91.3	5667
17	5	97.6	8900
18	11	101.5	9155
19	16	95.9	7350
20	9	94.6	7311
21	12	102.5	9716
22	13	109.9	10323
23	12	109.0	11125
24	19	107.8	11442
25	13	114.2	13131
26	13	115.2	13623
27	10	112.6	12900
28	12	114.0	12408
29	13	117.8	14538
30	12	112.2	12708
31	7	115.4	14414
32	10	115.4	13970
33	3	114.0	10967
34	6	115.8	13650
35	5	120.0	16280
36	6	125.5	16983
37	2	125.0	18000
38	2	108.5	10900
39	1	130.0	18400
40	2	143.0	25250
41			
42	5	117.0	13980
43			
44			
45			
46			
47	1	121.0	20900
48			
49	1	133.0	19000
Total	257	107.6	11378.9

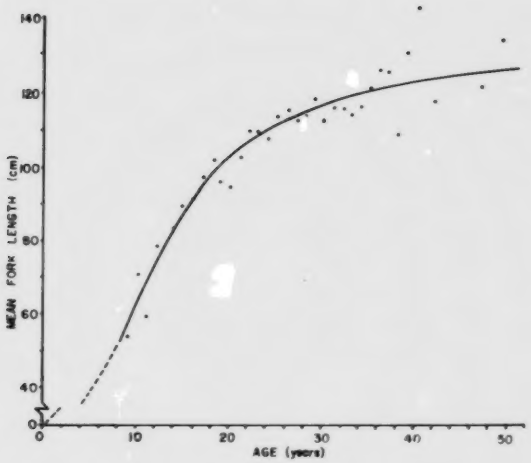

Fig. 2. Length-at-age for lake sturgeon from the Groundhog and Mattagami rivers.

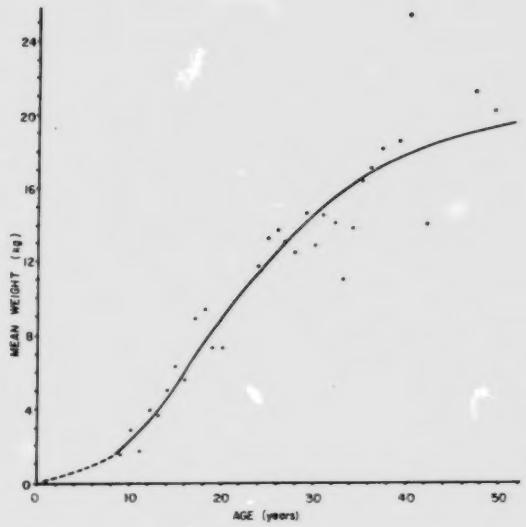

Fig. 3. Weight-at-age for lake sturgeon from the Groundhog and Mattagami rivers.

was made to calculate separate growth rates for males and females due to the small sample sizes of fish sexed.

Mean weight of 975 fish captured by the netting crew in 1984 was 10.68 kg, mean fork length was 105.1 cm, mean dressed length was 68.0 cm and mean condition factor was 0.86. Mean weight of angler-caught fish in 1984 was slightly higher at 11.60 kg. Gibson et al. (1984) noted a mean condition factor of 0.79 for Abitibi River sturgeon, somewhat lower than the 0.86 determined for sturgeon from the Groundhog River.

POPULATION ESTIMATE

Sturgeon from the study areas on both the Groundhog and Mattagami rivers were treated as a single population. A population estimate was calculated using the modified Schnabel formula (Ricker 1975) and mark-recapture data from the 1984 season (Table 2). The value of Ct (no. caught) x Mt (no. marked at large) was calculated on the basis of data collected during netting periods of unequal duration, ranging from 2 to 8 days. A total of 17 fish were discounted as recaptures, as they were recaptured shortly after release.

Sixty-four percent of the 16 fish which had lost their tags (presumably from entanglement in the gill nets) had been tagged in 1984. The ratio of 1984 recaptures to recaptures from all three years produced this figure. The population estimate was 8,429 sturgeon with 95% confidence limits of 6,260-11,654. Numbers of fish tagged, recaptures and mortalities during the study are summarized in Table 3.

FISH MOVEMENTS

Thirty-four of the 71 recaptures during the study had moved from the original tagging and release sites while 37 fish showed no movement. The longest migrations recorded were 22 km upstream and 26 km downstream (Table 4).

A number of recaptures indicated upstream movements of mature fish to spawning areas at Whist Falls and LaDuke Rapids in May and early June, followed by apparent movements downstream to work field 2 (the "Pot") in mid-June. Many mature fish appeared to remain in this area until late July and August when further downstream movements occurred towards the mouth of the Groundhog River and into the Mattagami River.

PRODUCTION AND BIOMASS

The number of fish caught and sampled in each age group was used to estimate the fraction of the total population (8,429) per age group (Table

Table 2. Sturgeon population estimate using 1984 mark-recapture data. See Schnabel's adjusted formula (3.17 in Ricker 1975).

No. caught (Ct)	No. recaptures (R)	No. marked	No. marked mortalities	No. marked at large (Mt)	Ct Mt
59	3	53	0	0	0
135	2	128	0	53	7155
209	16	193	0	181	37829
91	7	84	0	374	34034
13	1	12	0	458	5954
61	1	60	0	470	28670
196	4	192	0	530	103880
87	4	83	0	722	62814
102	4	98	0	805	82110
	R = 42				Σ = 362446

$$N = \frac{\Sigma(Ct\ Mt)}{(\Sigma R+1)} = \frac{362446}{43} = 8429$$

Confidence limits for N (Ricker 1975, App. II)

$$p = 0.95\ (31.1 \leq R \leq 57.9)$$

$$\frac{362446}{31.1} = 11654 \qquad \frac{362446}{57.9} = 6260$$

$$N = 8429 \qquad p = 0.95\ (6260 \leq N \leq 11654)$$

Table 3. A summary of tag return data.

Year	No. tagged	No. recaps. from 1982	No. recaps. from 1983	No. recaps. from 1984	No. recaps. yr unknown[a]	No. mortalities
1982	251	5	-	-	0	3
1983	330	6	9	-	1	1
1984	903	5	13	32	16	14

[a]For purpose of Schnabel population estimate 64% of these recaps. were considered to be from sturgeon tagged in 1984.

Table 4. Movement of recaptured sturgeon. No. of recaps = 71.

Distance (km)	No movement		Upstream		Downstream	
	No.	%	No.	%	No.	%
0 - 5			3	4.2	3	4.2
6 - 10			5	7.0	10	14.1
11 - 20			2	2.8	9	12.7
21+			1	1.4	1	1.4
Total	37	52.1	11	15.4	23	32.2

5). Annual production was calculated as the product of the mean annual increment in weight for the catchable population, calculated from Fig. 3 for ages 9 to 49 and the number of fish estimated for each age group. Total annual production (the sum of age group production) was 4,649 kg (3.98 kg ha^{-1}). Biomass was calculated as the product of the number of fish for each age group and the mean weight at each age group and was 98,950 kg (84.71 kg ha^{-1}). Hence, the ratio of annual production to biomass = 4,649/98,950 = 0.047.

MORTALITY

A catch curve was constructed using $\log_{10}$ of the number of fish caught in each age group (Fig. 4). The ascending and descending slopes were similar and the peak formed a broad dome. This indicates gradually increasing recruitment into the fishery over some 15 age groups due to slow relative growth and wide selectivity of fishing effort. Also, it may be noted that the peak occurs at 25 years compared to Threader's (1981) finding of seven years. This is probably a function of location of capture as well as fishing gear and angler preference for retaining larger fish. Many of the samples were collected from high density congregations of fish near spawning sites and post-spawning holding areas in late spring and early summer. Very little effort was made to locate and capture young fish. As a result, the younger age groups (pre-spawning) are poorly represented in the catch. Older fish (38+) were also sparsely represented, leaving the final trend of mortality rate in some doubt.

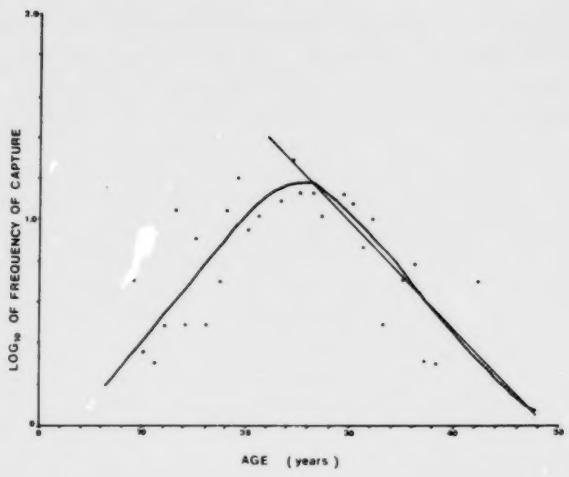

Fig. 4. The catch curve of netted and angler-caught lake sturgeon in the Groundhog and Mattagami rivers, 1982-1984. The diagonal line was used to calculate the instantaneous rate of total mortality, Z.

The slope of the descending limb of the curve in Fig. 4 is Z, the instantaneous rate of total mortality. In this case, the slope was calculated between ages 26 and 38, the most reliable portion of the curve, and the value of Z was 0.122. Survival calculated as $S = e^{-Z}$ was 0.885 and the total annual mortality rate (A) was 0.115.

The instantaneous rate of fishing mortality (F) was estimated by multiplying Z by the ratio of fishing deaths (398) to all deaths (969) to give 0.050. The instantaneous rate of natural mortality (M) was calculated by subtracting F from Z to arrive at a value of 0.072. The exploitation rate (u) determined from the relationship FA/Z was 0.047. For the above calculations, it was assumed that natural and fishing mortality were acting concurrently.

SEX RATIO AND MATURITY

The sex ratio based on a total of 42 angler-caught fish (21 males, 21 females) was 1:1. Of all fish sexed, 80% of the females and 75% of the males were considered to be mature. The earliest observed age of maturity for males was 19 and for females 22. However, since data for adjacent age groups were sparse and only one observa-

Table 5. Estimation of production and biomass for sturgeon from the Groundhog and Mattagami rivers.

Age	Sample size (no.)	Proportion of catch	No. in population (Pop. est. x col.2)	Mean weight[a] (g)	Annual growth increment (g)	Production (kg) (cols. 4x6)	Biomass (kg) (cols. 4x5)
9	5	0.02	169	1600	400	67.6	270.4
10	1	0.004	34	2100	500	17.0	71.4
11	2	0.008	67	2500	500	33.5	167.5
12	3	0.012	101	3200	600	60.6	323.2
13	11	0.043	362	3800	600	217.2	1375.6
14	3	0.012	101	4400	600	60.6	444.4
15	8	0.031	261	5100	700	182.7	1331.1
16	3	0.012	101	6000	900	90.9	606.0
17	5	0.020	169	6800	800	135.2	1149.2
18	11	0.043	362	7600	800	289.6	2751.2
19	16	0.062	523	8400	800	418.4	4393.2
20	9	0.035	295	9100	700	206.5	2684.5
21	12	0.047	396	9700	600	237.6	3841.2
22	13	0.051	430	10200	600	258.0	4386.0
23	12	0.047	396	10700	500	198.0	4237.2
24	19	0.074	624	11200	500	312.0	6988.8
25	13	0.051	430	11800	600	258.0	5074.0
26	13	0.051	430	12200	400	172.0	5246.0
27	10	0.039	329	12700	500	164.5	4178.3
28	12	0.047	396	13100	400	158.4	5187.6
29	13	0.051	430	13500	400	172.0	5805.0
30	12	0.047	396	13800	300	118.8	5464.8
31	7	0.027	228	14200	400	91.2	3237.6
32	10	0.039	329	14600	400	131.6	4803.4
33	3	0.012	101	15000	400	40.4	1515.0
34	6	0.023	194	15400	400	77.6	2987.6
35	5	0.019	160	15800	400	64.0	2528.0
36	6	0.023	194	16200	400	77.6	3142.8
37	2	0.008	67	16700	500	33.5	1118.9
38	2	0.008	67	17200	500	33.5	1152.4
39	1	0.004	34	17600	400	13.6	598.4
40	2	0.008	67	18000	400	26.8	1206.0
41			70	18500	500	35.0	1295.0
42	5	0.020	169	18900	400	67.6	3194.1
43			58	19400	500	29.0	1125.2
44			52	19800	400	20.8	1029.6
45			46	20200	400	18.4	929.2
46			43	20600	400	17.2	885.8
47	1	0.004	34	21000	400	13.6	714.0
48			36	21400	400	14.4	770.4
49	1	0.004	34	21800	400	13.6	741.2
Total	257	1.0	8429	11379		4648.5	98950.8

[a]Values read from weight-age curve in Fig. 3.

tion was made of each value, their significance is limited. The mean age of females captured was 27 years and of males 23.5 years.

CONTAMINANT ANALYSIS

Fish sampled for mercury were taken from the Mattagami River in work field 5 (Clay Township) in 1976 and from the Groundhog River, work field 3 (Tucker Township) in 1983. The mean concentration of mercury in 31 sturgeon from the Mattagami River in 1976 was 0.17 ppm with a range of 0.08 to 0.38. Lengths ranged from 104 to 140 cm. One fish registered 0.62 ppm, slightly over the allowable "safe" level for Canadian standards. The concentration of mercury in 20 fish from the 1983 Groundhog River survey averaged 0.11 ppm with a range of 0.04 to 0.42. Lengths ranged from 84 to 145 cm. The hazard of mercury contamination of sturgeon flesh is low in the study area.

CREEL SURVEY

Creel survey results are summarized in Table 6. In general, angler effort was concentrated in work field 2 (the "Pot") with 45 to 58% of the effort expended there. Work field 3 at the confluence of the Groundhog and Mattagami rivers was also a popular site for sturgeon anglers. Angler success was highest in June and August, but mean weight of the sturgeon kept was lowest in August. The proportion of fish kept to fish caught also decreased substantially over the season. Assuming a consistent angler preference, a change in sub-population structure is indicated. Post-spawning dispersal of the older segment could account for this change, as the larger sturgeon moved out of the "Pot" area later in the season.

Harvest estimates were adjusted in an attempt to compensate for unrecorded angler effort. Values were increased by an average of 21% based on missed angler interviews estimated from the boat count results. Harvest and yield in the study area between 1982 and 1984 ranged from 2,945 to 5,262 kg and 2.5 to 4.5 kg ha^{-1}, respectively. Approximately 55% of the total estimated harvest was taken at the "Pot" (work field 2). The presence of the survey crew probably reduced the illegal harvest to some extent.

A length-frequency distribution of angler-caught sturgeon (Fig. 5) indicated that most fish kept were in the 90 to 130 cm fork length range, similar to the size range most frequently captured in the large mesh gill nets (Fig. 6). The highest frequency of angler-kept

Table 6. A summary of creel survey data, 1982-1984.

	1982	1983	1984
Number of anglers surveyed	421	237	337
Actual hours fished	1612	1012	1519
Actual hours at the "Pot" only	N/A	590	707
Number of fish removed			
- sturgeon	82	42	43
- walleye	20	27	25
- northern pike (*Esox lucius*)	216	111	247
Mean weight of sturgeon kept (kg)	9.9	11.6	11.6
Estimated seasonal angler-hours	5913	12791	12414
Total CUE for sturgeon			
- June	0.08	0.04	0.11
- July	0.12	0.04	0.04
- August	0.12	0.11	0.06
Estimated sturgeon harvest (kg)	2945	5262	4612
Yield (kg ha^{-1})	2.5	4.5	3.9
Estimated sturgeon harvest at "Pot" (kg)	1850	2893	2639
Yield at "Pot" (kg ha^{-1})	122	190	174

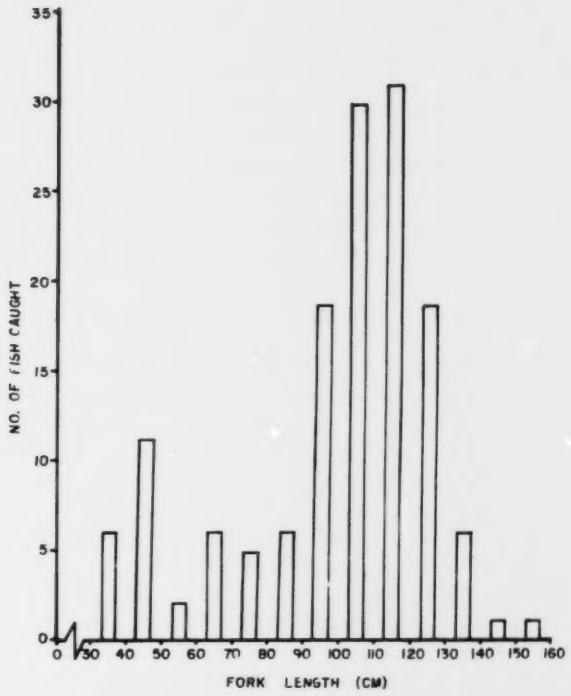

Fig. 5. Length-frequency distribution of angler-caught lake sturgeon in the Groundhog and Mattagami rivers, 1982-1984.

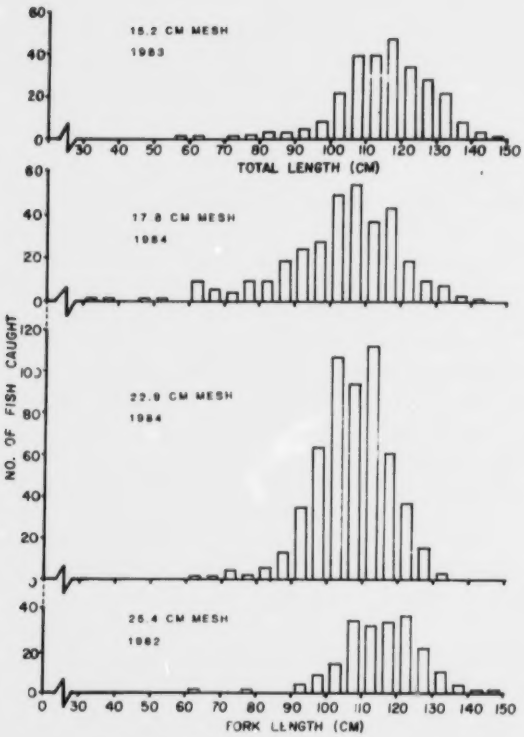

Fig. 6. Length-frequency distribution of lake sturgeon netted in the Groundhog and Mattagami rivers, 1982-1984.

fish were in the 101 to 110 cm and 111 to 120 cm fork length ranges.

MANAGEMENT IMPLICATIONS

Production calculated using a surplus production model provided an estimate of 4,649 kg yr^{-1} from a population of 8,429 sturgeon. Harvest was calculated from the 1984 creel survey at 4,612 kg and from the 1983 survey at 5,262 kg. Lawson (1983) found that harvest in 1982 totalled 2,945 kg which exceeded the previous maximum commercial harvest by about 300 kg. Thus, it appears that the Groundhog River sturgeon fishery is presently operating in a threshold situation at best. An additional problem may be the concentration of the harvest primarily in one small area (the "Pot"). While production and harvest estimates are admittedly crude approximations, they should nevertheless be of the correct order of magnitude. Therefore, production and angler harvest are close enough to preclude the re-opening of a commercial fishery. Further, the fishery may be overtaxed with the present angler harvest. Anglers maintain that the average size of fish they catch is decreasing. This is not supported by the mean weights of angler-caught fish sampled, but there appeared to be a decrease in the size of fish caught in the nets of the larger mesh sizes between 1983 and 1984.

Rather than considering the opening of a commercial fishery it is probably more appropriate to place constraints on the sport fishery. Harkness and Dymond (1961) noted that once overexploitation occurred a sturgeon stock did not recover to its original strength.

A forest access road is planned to cross the Groundhog River in the vicinity of LaDuke Rapids which will result in increased angler access and pressure. In order to protect this unique, highly productive sturgeon fishery, a fish sanctuary (May 1-July 15) has been proposed from LaDuke Rapids to the "Pot"

to protect sturgeon spawning at Whist Falls and LaDuke Rapids and post-spawners, many of which appear to remain at the "Pot" after spawning.

A longer term solution would be to impose a slot limit on all sturgeon, in order to protect most of the spawners. Males begin to mature at age 19 and females at age 22 at approximately 105 to 110 cm in fork length. To set a slot limit a fecundity study would be required, but a slot limit might be in the approximate range of 105 to 130 cm. This would still allow anglers to catch and keep a large sturgeon while protecting most of the spawning population.

A third alternative might be to establish a limited entry fishery based on allowable yield. Administration of this system would involve selection of participants through a lottery with each successful candidate being allowed to keep one lake sturgeon for the season. All sturgeon taken from the study area would have to be identified with a tag attached to the fish and mandatory registration could be a condition of the permit. An additional complication lies in determining the maximum allowable harvest which the sturgeon fishery can sustain. To date, no information is available on successful management of sturgeon for sustained yield in northern waters.

ACKNOWLEDGEMENTS

The authors wish to thank Chris Brousseau and Kathy Lawson for their advice regarding the data analysis. Thanks also to Ted Lucking, Cliff Rich and Louis Marion for their help in clarifying field methods and data recording and to Nicole Filion for typing the manuscript.

REFERENCES

CURRIER, J.-P., and G. ROUSSOW. 1951. Age and growth of lake sturgeon from Lake St. Francis, St. Lawrence River. Can. Fish Cult. 10:17-29.

DADSWELL, M.J. 1979. Biology and population characteristics of the shortnose sturgeon, *Acipenser brevirostrum* LeSueur 1818 (Osteichthyes; Acipenseridae), in the Saint John River estuary, New Brunswick, Canada. Can. J. Zool. 57:2186-2210.

ENVIRONMENT CANADA. 1983. Historical stream flow summary, Ontario to 1982. Inland Waters Directorate, Water Resources Branch, Water Survey of Canada, Ottawa. 523 p.

GIBSON, D. W., E. R. ARMSTRONG, and S. AUBRY. 1984. Age, growth and management of the lake sturgeon (*Acipenser fulvescens*) from a reach of the Abitibi River. Ont. Min. Nat. Resour., Cochrane District Ms. Rep. 38 p.

GODDARD, J. 1963. The lake sturgeon (*Acipenser fulvescens*) of Chipman Lake in the Geraldton Forest District of Ontario. Ont. Dep. Lands Forests Ms. Rep. 23 p.

HARKNESS, W. J. K. 1923. The rate of growth and the food of the lake sturgeon, *Acipenser fulvescens* (Lesueur). Univ. Toronto Stud. Biol. Ser. No. 24. Publ. Ont. Fish. Res. Lab. 18: 15-42.

HARKNESS, W. J. K., and J. R. DYMOND. 1961. The lake sturgeon. Ont. Dep. Lands Forests, Fish. Wildl. Br., Toronto. 121 p.

HUFF, J. A. 1975. Life history of Gulf of Mexico sturgeon, *Acipenser oxyrhynchus desotoi*, in Sawannee River, Florida. Fla. Dep. Nat. Resour., Marine Res. Lab. Publ. 16. 31 p.

LAWSON, K. 1983. Age, growth and biology of the lake sturgeon (*Acipenser fulvescens*) in the Groundhog River, Kapuskasing District. Ont. Min. Nat. Resour., Kapuskasing Dist. Ms. Rep. 49 p.

NOWAK, A. M. 1984. Status of the lake sturgeon fishery lower Groundhog River, Kapuskasing District. Ont. Min. Nat. Resour., Kapuskasing Dist. Ms. Rep. 67 p.

PRIEGEL, G. R., and T. L. WIRTH. 1978. Lake sturgeon populations, growth, and exploitation in lakes Poygan, Winneconne, and Lake Butte des Morts,

Wisconsin. Wisc. Dep. Nat. Resour. Tech. Bull. 107. 23 p.

RICKER, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191. 382 p.

ROUSSOW, G. 1957. Some considerations concerning sturgeon spawning periodicity. J. Fish. Res. Board Can. 14: 553-572.

THREADER, R. W. 1981. Age, growth and proposed management of the lake sturgeon (*Acipenser fulvescens*) in the Hudson Bay lowland. Ont. Min. Nat. Resour., Moosonee District Ms. Rep. 106 p.

BIOLOGY OF THE LAKE STURGEON (*ACIPENSER FULVESCENS*) IN THE KENOGAMI RIVER, ONTARIO

A. P. Sandilands
Ecologistics Limited, 50 Westmount Road North, Waterloo, Ontario N2L 2R5

A mark-recapture study of lake sturgeon (*Acipenser fulvescens*) was conducted in 1984 and 1985 on the Kenogami River, northeast of Geraldton, Ontario. Density and biomass estimates varied greatly among three stretches of the river, and variation may have been due to habitat preferences and interspecific competition. Age of fish caught ranged from 2 to 60 years, with females growing faster and living longer than males. Females became mature at 25 to 31 years of age, and males first spawned at ages 21 to 25. Some sturgeon moved as far as 150 km from the original site of capture, suggesting that there were migrations upstream in spring and downstream in fall. Sturgeon ate aquatic invertebrates almost exclusively, with larger fish actively selecting for crayfish. Caddisfly larvae and dragonfly nymphs were an important component of the diet of juvenile and adult sturgeon. Of the four other bottom-feeding species of fish present, only the shorthead redhorse (*Moxostoma macrolepidotum*) appeared to be a significant competitor. Predictions of sustainable yield were not possible. However, population sizes at Kapeesawatan Lake and Ogahalla are small and preclude establishment of a commercial fishery at either location. The subsistence fishery for sturgeon at Ogahalla and Mammamattawa should be closely monitored.

INTRODUCTION

In 1984, a study of the lake sturgeon (*Acipenser fulvescens*) on the Kenogami River was initiated on behalf of the Geraldton District of the Ontario Ministry of Natural Resources (OMNR). Data on this stock of sturgeon were collected over two field seasons. The primary goal of the study was to predict the sustainable yield of lake sturgeon for the study area. Data were collected on age distribution, size at age, growth rate, mortality rate, standing crop, fecundity, age at maturity, spawning periodicity, sex ratios, movement patterns, habitat preferences and interspecific competition.

THE STUDY AREA

The Kenogami River is a tributary of the Albany River which flows into James Bay. At the outset of the project, the study area was defined as the river from Kapeesawatan Lake downstream approximately 62 km to the eastern extent of the Geraldton District. The study area was enlarged in 1985 to include a section of the river in Hearst District.

Three distinct areas were sampled: Kapeesawatan Lake and 15 km of the river immediately downstream of it, the Ogahalla rapids, and the main river at Mammamattawa (Fig. 1). Most of the area between the sampling sites was either inaccessible, or too shallow for the gear to operate efficiently.

Kapeesawatan Lake is small and shallow, with a surface area of 22.8 ha and an average depth of approximately 1.3 m. The maximum depth recorded was 4.8 m. A third of the lake is dominated by emergent vegetation. The river below it is primarily slow-flowing (average water velocity 12 cm sec^{-1}). This stretch of river is moderate in depth, averaging approximately 2.5 m with a maximum depth of 7.5 m, with one riffle area. This is the only site with extensive growths of submergent aquatic vegetation in the study area. The lower end of the first portion of the study area is marked by a 4 m waterfall which is followed by approximately 3 km of rapids.

The Ogahalla study area is located at the base of this extensive stretch of rapids. The river here is faster flowing, averaging 45 cm sec^{-1}. In the 5 km stretch that is navigable, water

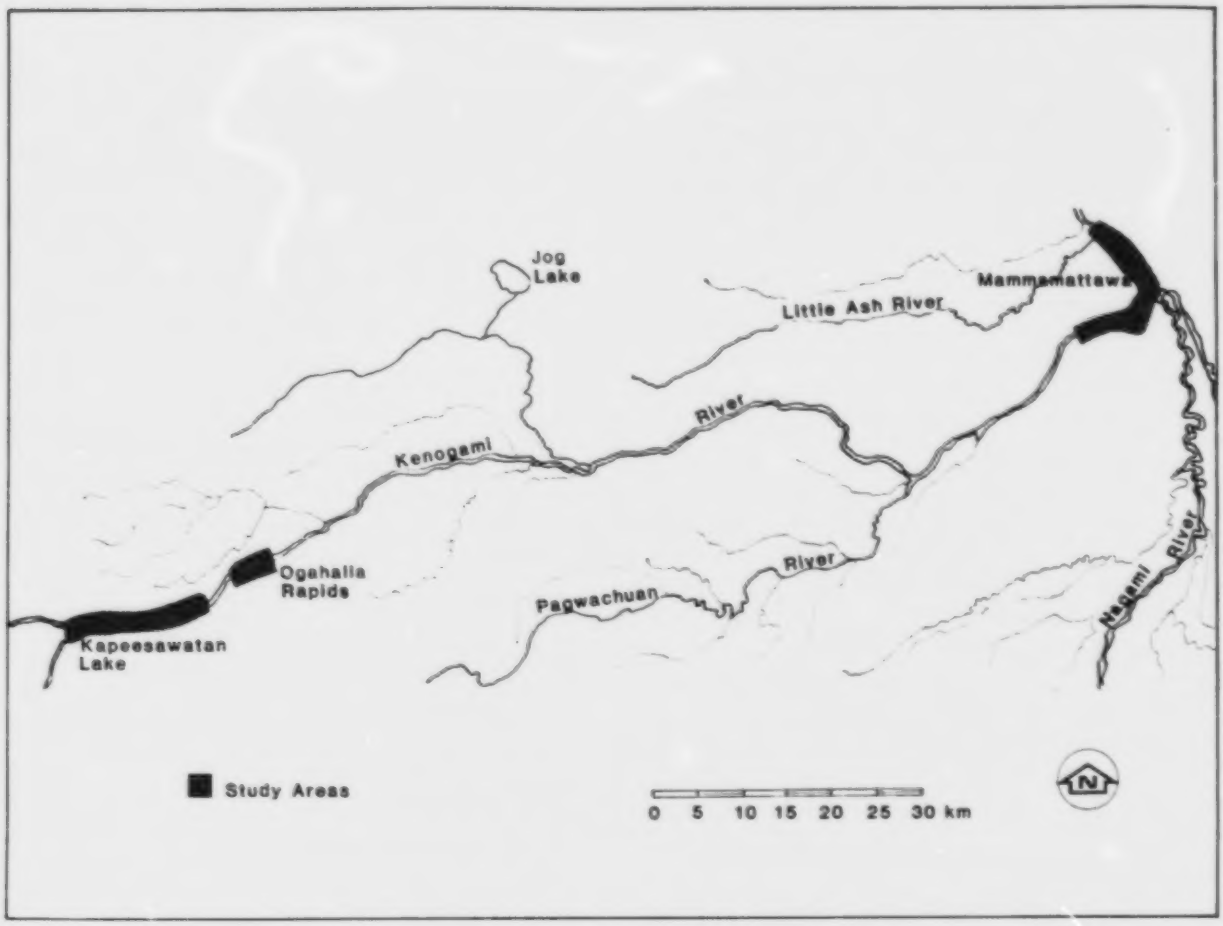

Fig. 1. Kenogami River study areas.

depth averages 2.5 m with a maximum depth of 5.0 m. Aquatic vegetation is rare to absent and, similar to the upstream areas, the river is approximately 60 m in width.

In the intervening 120 km between Ogahalla and Mammamattawa, which is not part of the study area, the river is shallow (1 to 2 m) and swiftly flowing over limestone bedrock or gravel.

At Mammamattawa, the river is much larger and still moderate to fast flowing (averaging 41 cm sec^{-1} in July, 64 cm sec^{-1} in September). Width is 170-225 m, but depth only averages 2.0 m with a maximum of 4.5 m. Vegetation is restricted to shoreline emergents.

MATERIALS AND METHODS

FIELD METHODS

Kapeesawatan Lake and the Ogahalla study area were sampled July-September 1984 and in late May and early June 1985, whereas Mammamattawa was sampled in late June and late September 1985. Gill nets were the primary gear used with mesh sizes ranging from 3.8 to 30.5 cm (stretched measure) in 1984 and 2.5 to 30.5 cm (stretched measure) in 1985. Setlines were used unsuccessfully in 1984, but with improvements in their design they caught fish in 1985. Attempts to catch sturgeon using fyke nets, seines and electrofishing gear were not successful.

All sturgeon captured were measured for total length (TL) and fork length (FL) to the nearest millimeter. Depending upon the size of the fish, they were weighed to the nearest gram (0 to 300 g), 0.25 kg (.3 to 12 kg) or 0.5 kg (>12 kg). The first pectoral fin ray was removed with side-cutters for aging. Live fish were tagged with numbered Floy FD-67 tags inserted under the anterior base of the dorsal fin and then released. Dead fish were sexed, using the colour plates in Dadswell (1979) and the description in Cuerrier (1966). Stomachs from dead fish were removed and preserved in 10% buffered formalin.

In 1985, sex was determined surgically on live sturgeon. After anaesthetizing them with MS-222 (tricane-methane sulphanate), an incision approximately 5 cm in length was made in the belly using a sterilized scalpel. After viewing the gonads, the incision was sewn up with surgical sutures and fish were released after recovering from the anaesthetic. For determination of fecundity, the ovaries from dead fish were removed and preserved in 2% formalin.

Length, weight, sex, maturity and age of all other fish species captured were recorded. Stomach contents of all piscivorous fish were examined in the field, while subsamples of stomachs of bottom feeding fish were preserved in 10% buffered formalin.

LABORATORY METHODS

To determine fecundity, the total volume of two ovaries were measured first and then a subsample was taken to find the number of eggs per unit volume. In analyzing stomach contents, all material in the alimentary canal of sturgeon and suckers was examined. Invertebrates were identified to the lowest level possible and the number and volume of each taxon in each stomach recorded. The percent volume and occurrence of each prey item in each stomach was determined and an overall average calculated to assess the relative importance of prey items.

Catch-per-unit-effort (CUE) for gill nets is reported as number of fish caught in 24 hours per 91.4 m (300 feet) of net. For setlines, CUE is reported as number of fish caught in 24 hours per 50 baited hooks.

RESULTS

AGE AND GROWTH

Over a two year period, 283 sturgeon were sampled:

Location	Sample size 1984	1985	Total
Kapeesawatan Lake	38	10	48
Ogahalla	37	16	53
Mammamattawa	-	182	182
Total	75	208	283

The age composition of Kenogami River sturgeon for 1984 is shown in Fig. 2. The mean age of sturgeon caught in that year was 30 and the youngest fish caught was nine. It is uncertain to what extent this reflected the true population distribution in Kapeesawatan

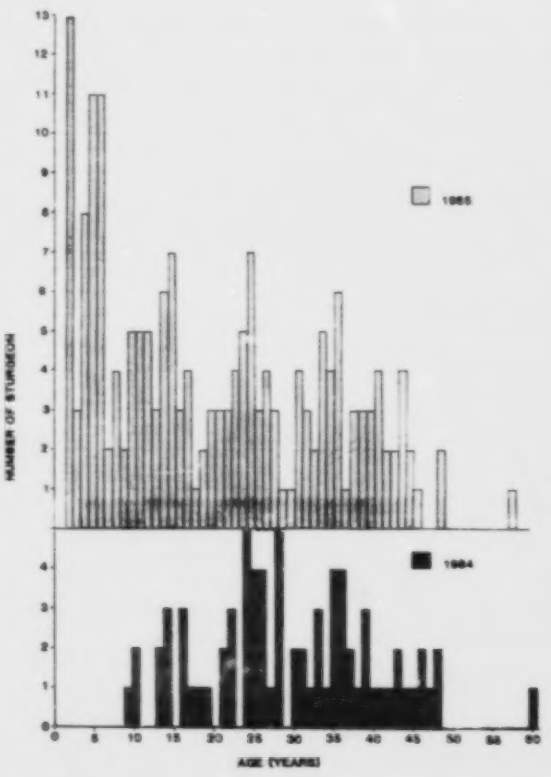

Fig. 2. Age distribution of sturgeon from the Kenogami River.

Lake and at Ogahalla, or whether gear selectivity resulted in a higher than normal average age. However, since sampling in those two areas in 1985 with small mesh nets resulted in no fish younger than 23 years being caught, there does appear to have been an absence of juvenile fish in the population.

The greater range of sturgeon ages observed in 1985 was probably due to fish from the Mammamattawa site. Ages ranged from 2 to 58 (Fig. 2) with a mean age of 20 years. All ages between 2 and 46 were represented in the sample.

Length- and weight-at-age relations for Kenogami River sturgeon are shown in Fig. 3. Variations in growth may be due to sampling errors, aging errors, or to the fact that data from three different sites were combined. Sturgeon increased rapidly in length until about age 10, after which the growth rate declined. The rate of growth in weight was considerably less than for length, but increased rapidly after age 25-30. Growth data presented separately by sex (Fig. 4) show that females grew faster than males in both length and weight and had greater longevity. There was also a greater variation in weight-at-age for the female fish than for the males.

A weight-length relation for Kenogami River sturgeon is shown in Fig. 5. This relation can be expressed as $W = 0.0015L^{3.2778}$ ($r^2 = 0.9827$), where W is weight (g) and L is total length (cm).

The sex ratio of male to female sturgeon was: Kapeesawatan Lake, 1:8.00; Ogahalla, 1:0.18; and Mammamattawa, 1:0.34.

GEAR SELECTIVITY AND CATCH-PER-UNIT-EFFORT

Table 1 summarizes selectivity of gear for sturgeon by area in 1985. Data from 1984 are not included in the table, as only larger mesh nets were used, and the design of setlines was inadequate to catch sturgeon.

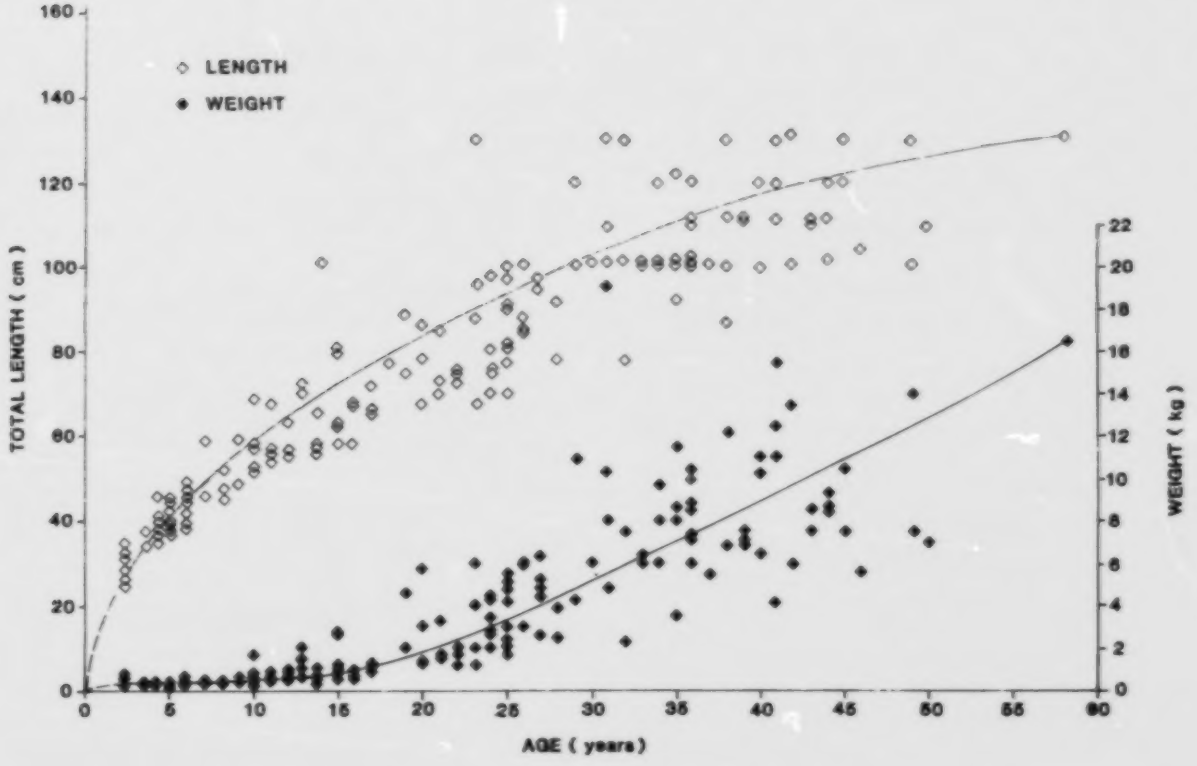

Fig. 3. Length- and weight-at-age for Kenogami River sturgeon.

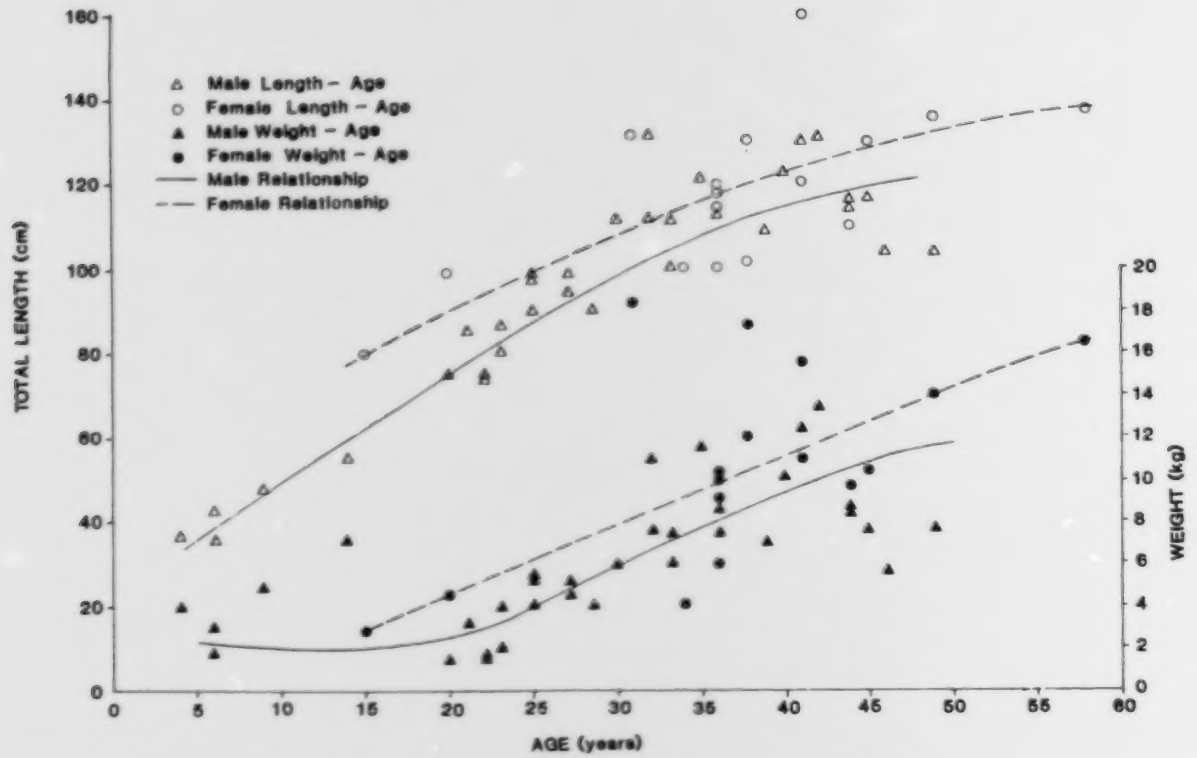

Fig. 4. Length- and weight-at-age for male and female sturgeon from the Kenogami River.

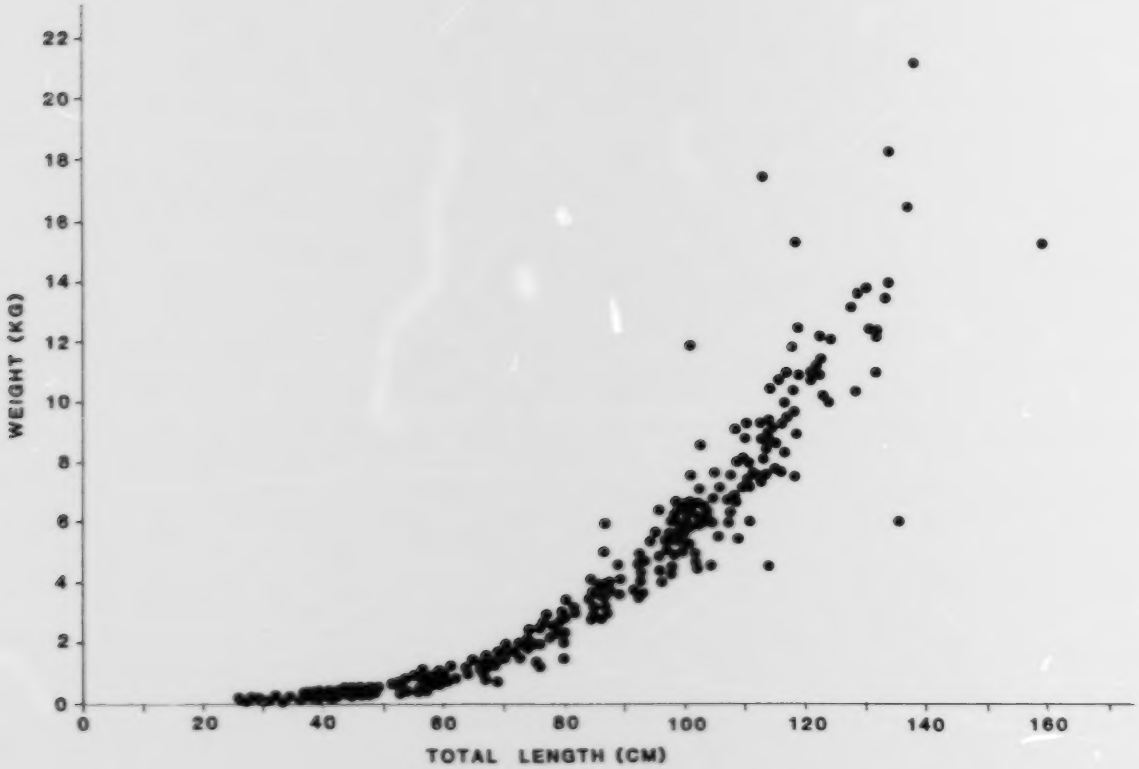

Fig. 5. Weight-length relation for sturgeon from the Kenogami River.

Table 1. Gear selectivity and catch-per-unit-effort for sturgeon.[a]

Mesh size (cm)	Kapeesawatan Lake			Ogahalla			Mammamattawa		
	Number caught	Average TL (cm)	CUE	Number caught	Average TL (cm)	CUE	Number caught	Average TL (cm)	CUE
Experimental[b]				0	-	0.00	8	54.2	1.15
4.5				0	-	0.00			
5.0							3	28.5	0.74
5.7	0	-	0.00				9	39.5	1.38
6.4							1	31.7	0.48
7.0	0	-	0.00				6	43.4	1.10
7.6				0	-	0.00			
8.9	0	-	0.00	3	116.7	0.24	60	53.5	1.90
10.2	0	-	0.00						
11.4							4	60.9	0.93
14.0	0	-	0.00				17	70.7	2.41
17.8	1	107.2	0.07				0	-	0.00
22.9	2	112.7	0.15	5	115.1	0.23	3	85.1	0.09
24.1				4	103.0	0.38	1	102.0	0.05
25.4	9	109.8	0.27	6	120.3	0.57	0	-	0.00
30.5	2	126.1	0.20	0	-	0.00	7	86.2	0.12
Setlines	0	-	0.00	0	-	0.00	67	93.9	2.31

[a] A blank space indicates the gear was not fished.
[b] Data from these nets were not assigned to individual mesh sizes.

Despite the use of small mesh nets (down to 5.7 cm) at Kapeesawatan Lake, no small sturgeon were captured (Table 1). All fish caught at this location were in excess of 100 cm in length and first became susceptible to gill nets of mesh size 17.8 cm. The average size of sturgeon caught increased with mesh size.

At Ogahalla, the average size caught by all mesh sizes fished was also over 100 cm (Table 1). The largest sturgeon were caught in the 25.4 cm mesh and none were caught in the 30.5 cm mesh.

At Mammamattawa, the size of sturgeon captured increased with the mesh size used. Compared to Kapeesawatan Lake and Ogahalla there were fewer large sturgeon, as evidenced by the absence of fish in the 25.4 cm mesh and the presence of smaller fish in the 30.5 cm mesh. The setlines caught fish that averaged 93.9 cm (TL).

CUE was very low for all gear at Kapeesawatan Lake and Ogahalla, with only larger mesh nets capturing sturgeon (Table 1). Highest CUE at Mammamattawa was for the 14.0 cm mesh, followed by setlines and the 8.9 cm mesh. Setlines were much more effective in fall, with an autumn CUE of 4.15 compared to 0.29 in the summer. Larger mesh nets set at Mammamattawa generally had a lower CUE than at the other two study areas.

MATURITY AND FECUNDITY

In spite of the large subsample of sturgeon sexed, information on maturity is incomplete. Generally, sexes could not be distinguished until 6 to 15 years of age and both the sex and state of maturity could not be determined for a 21 and a 24 year old fish. The youngest males to approach maturity were 20 and 21 years old. Presumably, these fish would be capable of spawning the following spring. Two other males, at ages 22 and 23, were still immature and had probably not spawned previously. Only six females were close to maturity, with the youngest being 31 years old. The youngest fish in the sample that had spawned in 1985 were two males at age 33

and three females at age 41.

Fecundity data were available for only two sturgeon. Egg diameter averaged 2.75 mm and the fecundity data were as follows:

	Total length (cm)	Weight (kg)	Est. no. of eggs	Eggs kg^{-1} live weight
Mean	130.7	13.3	120,998	8,797

STANDING STOCKS

In 1984, the total population in the 20 km stretch between Kapeesawatan Lake and Ogahalla using the modified Schnabel formula (Ricker 1975) was estimated at 101 sturgeon (Table 2). Population estimates were also prepared for these two areas separately, as it was thought that the waterfall between the two sites might be a barrier to upstream movement so that discrete populations might occur. The estimate for both areas was 55 fish, but densities of fish were much greater at Ogahalla than Kapeesawatan Lake.

In 1985, the population estimate at Kapeesawatan Lake declined to 10 fish. A shorter length of river was sampled below the lake, as higher water levels made one area of rapids impassable, but densities were still lower in 1985 than 1984. The Ogahalla population estimate was very similar both years, with a slight decline noted in 1985.

The population estimate of Mammamattawa in the summer of 1985 was 670. No population estimate was possible based upon the fall field work alone, because none of the sturgeon tagged in the autumn were recaptured. Combining the summer and fall data resulted in an estimate of 1314 sturgeon at Mammamattawa, with a density of 75.1 fish km^{-1}. Over the two sampling periods at Mammamattawa, five sturgeon were recaptured, a number only slightly above the minimum recommended by Robson and Regier (1964) for making a population estimate.

MOVEMENT PATTERNS

In 1984, 28 of 34 sturgeon recaptures were caught in the vicinity of the original capture and release sites. The majority of fish exhibiting movement were recaptured within 1 to 3 days and had only moved 1 to 3 km. The predominant direction of movement was downstream, although three sturgeon exhibited a slight upstream movement. Three sturgeon moved downstream comparatively long distances of 12 to 13 km, covering these distances in 12 to 24 days. One sturgeon originally caught in Kapeesawatan Lake was later captured at Ogahalla. Due to the study design of fishing at Kapeesawatan Lake in summer and Ogahalla in fall, extensive upstream movements would not have been detected.

In 1985, two sturgeon tagged the previous year were recaptured in Kapeesawatan Lake. The first was initially tagged 4 km below the lake and it was subsequently recaptured twice in the lake. The second was first tagged at Ogahalla and had moved up through the rapids and over the waterfall and was caught 22 km upstream. It also was caught again in the lake. Two other

Table 2. Modified Schnabel population estimates (N) for sturgeon.

Area	Year	N	95% C.L.	No. km^{-1} river
Kapeesawatan Lake	1984	55	41-72	2.9
Ogahalla Rapids	1984	55	41-72	12.5
Kapeesawatan to Ogahalla	1984	101	82-123	4.3
Kapeesawatan Lake	1985	10	5-18	1.9
Ogahalla Rapids	1985	48	35-63	10.9
Mammamattawa (summer)	1985	670	620-723	38.3
Mammamattawa (summer, fall combined)	1985	1314	1244-1387	75.1

sturgeon caught in the lake were recaptured two and four times, respectively, in different areas of the lake.

Two sturgeon tagged in 1984 were caught at Ogahalla in 1985, but the tags had been lost and the release sites of these fish could not be positively identified. One of these fish was subsequently recaptured.

Four sturgeon were recaptured in the summer at Mammamattawa, all within 1.5 km of the initial capture site. An additional four sturgeon were caught in the fall: one had lost its tag which prevented identification of the release site; one was captured 7.2 km downstream of the first capture site; one originally tagged at Ogahalla had moved approximately 130 km over a period of 113 days; and one first tagged in Kapeesawaten Lake had travelled downstream almost 150 km, also over a period of 113 days.

MORTALITY AND RECRUITMENT

In an effort to obtain some estimate of mortality for Kenogami River sturgeon, a catch curve grouped by five-year age-classes was prepared (Fig. 6). Recruitment to the stock that was being sampled occurred primarily between ages 2 and 6. This was the ascending portion of the catch curve when numbers of all age-classes were plotted. The annual mortality rate for the entire population (ages 7 to 60) was estimated at 4.6%. There was a distinct increase in mortality after age 45: mortality of sturgeon, ages 7 to 45, was 1.2% and mortality of age-classes 45 to 60 was 13.4%. The younger age-classes up to about age 25-30 are subject only to natural mortality, but fish in the older age-classes are susceptible to the setlines used in the native subsistence fishery.

BIOMASS AND YIELD

In Kapeesawatan Lake, 10 sturgeon were captured and the total estimated number of sturgeon present was 10. If one assumes that these fish represented the entire population, the biomass present was 116.6 kg or 3.33 kg ha^{-1}. The upper confidence limit results in an estimate of only 6.0 kg ha^{-1}. Annual

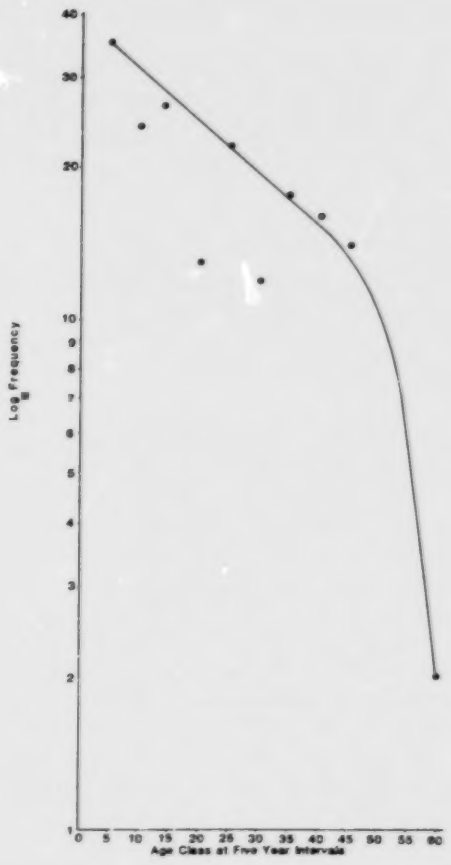

Fig. 6. Catch curve for Kenogami River sturgeon.

increase in biomass for this entire portion of the study area may be as little as 4.3-7.7 kg (0.12-0.22 kg ha^{-1}).

Using the same methodology for the Ogahalla stock and assuming that the entire population has the same age structure as the sample, the following biomass estimates and their 95% confidence limits were obtained: total biomass, 363 kg (265-476), or 13.75 kg ha^{-1} (10.0-18.0); annual increase in biomass 45.5 kg (33.2-59.8), or 1.3 kg ha^{-1} (0.9-1.7). Due to the problems in estimating population size at Mammamattawa, no biomass or yield approximations were attempted.

FEEDING HABITS

The diet of sturgeon was comprised almost entirely of invertebrates, except for some vegetation and small stones that may have been ingested accidentally

(Table 3). Crayfish (*Orconectes virilis*) were the predominant food by volume. A high proportion of sturgeon stomachs contained only crayfish and some had as many as six crayfish with total volumes in excess of 50 ml. Molluscs were only of moderate importance, comprising 10.5% of the volume of food eaten. Most of the remaining items eaten were aquatic insects. Juvenile sturgeon fed primarily on aquatic insects, particularly caddisflies and dragonflies. As sturgeon approached 80 cm in length, they started to select for crayfish.

INTERSPECIFIC COMPETITION

Stomachs of all piscivorous fish were examined in the field, none of which contained sturgeon or their remains. Brook trout (*Salvelinus fontinalis*), northern pike (*Esox lucius*), burbot (*Lota lota*) and walleye (*Stizostedion vitreum vitreum*) fed primarily on fish and other vertebrates. However, each of these fish species consumed invertebrates, including crayfish and dragonflies. Of the predatory species, the diet of the brook trout most closely approached that of the lake sturgeon. Stoneflies, caddisflies, dragonflies and crayfish were all consumed, but molluscs were avoided. Brook trout were rare in the study area, so they did not pose any serious competition to sturgeon. Lake whitefish (*Coregonus clupeaformis*) was the only bottom-feeding species that ate fish eggs. These were thought to be sucker eggs based upon size and colour. None of the sturgeon stomachs examined contained fish eggs or fish remains.

Table 3 summarizes the diet by volume of the five species of bottom-feeding fish found in the study area. Dietary competition between lake whitefish and sturgeon was minimal. Snails were a minor component of the sturgeon's diet, but were the predominant prey of lake whitefish, followed by mayflies. *Stagnicola catascopium* and *Gyraulus parvus* were the most frequently eaten snails, which were the same species consumed by sturgeon.

Table 3. Comparison of food items in the diet of five species of bottom-feeding fish.

Food items	Lake sturgeon N = 34 % by volume	Lake whitefish N = 15 % by volume	Longnose sucker N = 14 % by volume	White sucker N = 15 % by volume	Shorthead redhorse N = 8 % by volume
Stones	3.9	-	-	-	-
Vegetation	0.8	3.5	-	0.2	0.5
Nemerteans	-	-	-	1.4	-
Oligochaetes	-	3.1	-	4.5	6.3
Leeches	-	0.2	-	2.0	-
Horsehair worms	+	-	-	-	-
Amphipods	-	0.9	-	-	-
Crayfish	71.8	-	-	-	-
Stoneflies	1.3	0.5	0.9	0.4	2.1
Mayflies	0.8	16.1	1.4	28.9	3.2
Dragonflies	5.6	0.2	0.1	1.2	12.7
Hemiptera	-	3.1	-	-	-
Dobsonflies	+	-	-	-	-
Caddisflies	4.6	3.1	26.4	19.8	70.4
Beetles	-	0.9	-	-	-
Diptera	+	1.9	71.2	0.8	4.2
Snails	3.5	66.0	-	-	-
Clams	7.0	0.5	-	40.9	0.5

- = Absent.
+ = Volumes too small to measure.

Longnose suckers (*Catostomus catostomus*) fed almost exclusively on diptera (mostly blackflies) and caddisflies. There is a slight overlap in diet with sturgeon, but longnose suckers were relatively rare in the study area.

The three primary foods of white sucker (*Catostomus commersoni*) were clams, mayflies and caddisflies. Fingernail clams and small Unionid clams formed the bulk of food eaten and these were also of limited importance to sturgeon. The mayflies and caddisflies consumed were not the same families eaten by sturgeon.

Shorthead redhorse (*Moxostoma macrolepidotum*) ate primarily caddisflies and dragonflies. Important caddisfly families were Hydropsychidae and Leptoceridae. These two families of caddisflies were also important to the diet of sturgeon.

CURRENT HARVEST

Current harvest of Kenogami River sturgeon is low. There are no commercial licenses and harvest is limited to subsistence fishing by natives using setlines. In Kapeesawatan Lake, annual harvest is very near zero. At Ogahalla probably only 10-15 fish are taken annually, or 100 to 150 kg yr^{-1}. Mammamattawa receives greater pressure, with up to 65 sturgeon weighing 500-650 kg taken annually. It is not known if there is any fishing pressure on sturgeon further downstream of Mammamattawa.

DISCUSSION

The growth of sturgeon in the Kenogami River (Fig. 7) is slower than in Lake Nipigon and the St. Lawrence River (Harkness and Dymond 1961), but is faster than in the more northerly La Grande River (Magnin 1977). These differences may be due to different temperature regimes or to the availability of food.

Threader (1981) concluded that female sturgeon in the Moose River, Ontario, could spawn as early as age 20, but that males were not sexually mature

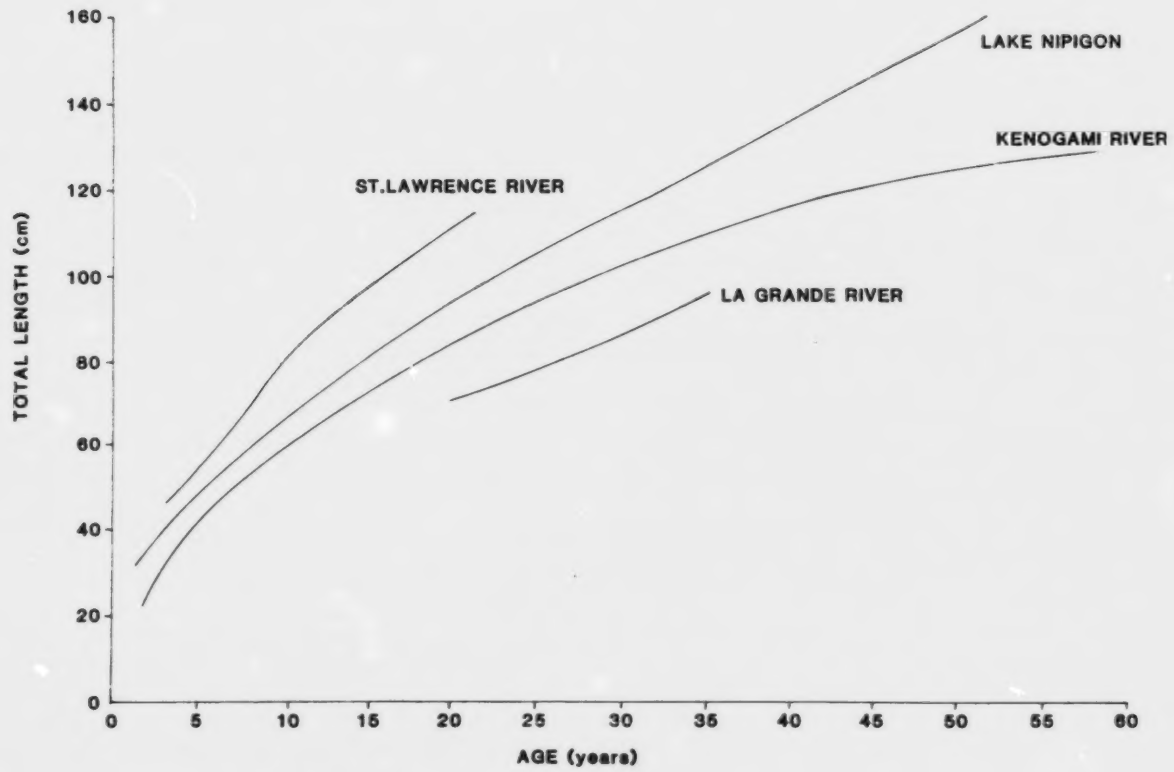

Fig. 7. Growth of lake sturgeon from different locations.

until 25. This is unusual in that males typically mature earlier than females. Preliminary results suggest that Kenogami River males may not mature until at least 21-25 years of age and females until ages 25-31. This is consistent with ranges reported for first spawning from a variety of locations by Harkness and Dymond (1961): males, 12-20; females, 14-33. In most areas, females are older than 23 years at first spawning.

Sturgeon appeared to congregate in large densities in areas of suitable habitat and be present in low numbers in less favourable areas. Extrapolation of density estimates from one stretch of a river to a long reach is therefore not appropriate. The numbers of sturgeon at Kapeesawatan Lake and Ogahalla would have been grossly overestimated if it had been assumed that the entire river had a homogeneous sturgeon density similar to that sampled at Mammamattawa.

If a population estimate is formulated on a short-term netting program, results are unlikely to reflect seasonal variations in populations. Densities of fish and the effectiveness of different gears in a given area vary seasonally. As many fish were caught during the fall at Mammamattawa as in summer with less than half the effort. This was attributed to the movement of sturgeon into shallower, cooler water in the fall and an influx from upstream populations. Setlines were very effective in fall, but inefficient in spring and summer.

Although data are limited and preliminary, they suggest that sturgeon are relatively sedentary during the summer, but that there may be upstream movements in the spring and downstream movements in the fall. At least one fish was capable of ascending the rapids and waterfall above Ogahalla that were presumed to be a barrier. It is possible that sturgeon leave the upper reaches of the river in the fall, where habitat appears to be less suitable and return early in the spring.

Movement patterns are not well understood in this case, but they have important management implications. Fish that appear to be residents of a particular stretch of river may actually be subject to exploitation elsewhere during another time of the year.

Few studies have been successful in defining lake sturgeon movements. MacRitchie (1981) found sturgeon in the Frederick House River to be relatively immobile with maximum observed movements of 5 km over a period of 65 days and very few movements through rapids. Scott and Crossman (1973) thought that sturgeon moved from shallow waters to deeper areas in summer, back to shallow areas in fall and then again to deep areas in winter. Spawning migrations are often as long as 125 km and may be as far as 400 km. Both strong homing and wandering have been reported for this species. Priegel and Wirth (1971) concluded that they travel widely within their home ranges and leave these areas only to travel upstream to the spawning areas. After spawning, they return again to the home range.

Mortality rates appeared to be very low, but better sample distribution and a more uniform effort of various fishing gears is required to accurately determine mortality rates. Other reported lake sturgeon mortality rates are: Moose River, 12.9% (Threader 1981); St. Lawrence River, 25.4% (Jolliff and Eckert 1971); Black Lake, Michigan, 9.7%; Menominee River, Michigan, 9.3% (Baker 1980). Priegel and Wirth (1975) estimated mortality rates in Lake Winnebago, Wisconsin, to be 5.4% for fish 13-36 years of age and 13.4% for older fish. All of these populations are subjected to fishing.

Because of the low confidence that can be placed on population estimates and mortality rates at this time, no quantitative estimate of recruitment was undertaken. Instead, some general observations are offered. At Kapeesawatan Lake, there appears to be no spawning and therefore, no recruitment to the stock through reproduction. Recruitment to this stock must be from fish ascending the Ogahalla rapids, or from fish descending the extensive rapids above the lake. It is thought that recruitment from either source is minimal.

The situation at Ogahalla is very similar, although two females that were

captured appeared to have spawned in this area. However, no fish younger than nine years of age were caught here during two sampling periods, so recruitment from young may be negligible. The stock appears to consist of a small population which remains stable during the summer. Individuals may leave in fall or immigrate in spring, but it is not known if the same individuals return annually, or if a different population is present each year.

At Mammamattawa, it is not known if recruitment occurs through spawning in the immediate vicinity, or if young sturgeon migrate from other spawning areas into the section of river that was sampled.

Because of the small sample size, low confidence in population estimates, poorly defined mortality rates and minimal number of recaptures from year to year, meaningful estimates of biomass and yield cannot be made at this time. Differences in growth rate between sexes and the wide variations in weights between age groups further complicates preparation of a yield model. The data collected during this study were not sufficient to prepare a biomass yield model similar to that of Semakula and Larkin (1968).

The diet of Kenogami River sturgeon was similar to that reported in several other studies, except for the preponderance of crayfish. Magnin (1977) found that mayflies and molluscs were most prevalent in the diet of sturgeon from the Opinaca, La Grande and Waswancipi rivers in Quebec. In Lake Waswancipi and the Waswancipi River, Quebec, sturgeon ate mostly caddisflies, mayflies, diptera, stoneflies and dragonflies (Magnin and Harper 1970). Molluscs were not numerically common, but comprised the bulk of some individual diets. Smaller fish depended almost entirely upon aquatic insects for food, while larger sturgeon also ate snails and clams. In Lake Winnebago, Wisconsin, sturgeon fed primarily on chironomid larvae and leeches (Probst and Cooper 1955). Molluscs were rare in stomachs and crayfish absent. Harkness and Dymond (1961) reported that mayfly nymphs formed the greatest bulk of sturgeon diet, followed by molluscs. They stated that crayfish are often considered to be a preferred food of sturgeon when they are present, but very few studies have reported them. An analysis of sturgeon stomachs from the Ogoki River, another tributary of the Albany River, revealed that snails were the most important food item. Crayfish formed 31.5% of the diet by volume, less than half the volume found in Kenogami fish. Differences between the diet of these two populations may be due to the fact that all the Ogoki sturgeon were caught in lacustrine habitats. The shorthead redhorse was the only other bottom-feeding fish species that appeared to actively compete with sturgeon for food in the Kenogami River.

The numbers of sturgeon present may be directly related to the physical habitat, including substrate, water velocity and size of the river. In Kapeesawatan Lake, the substrate is silt or fine granules and the current is negligible. As one progresses downstream, the flow velocity increases and the substrate becomes coarser and harder. At Mammamattawa, water velocities are high, the substrate is gravel and the river is three to four times as wide. Moreau and Legendre (1979) attempted to relate CUE of various fish species to habitat types. Contrary to this study, they found sturgeon to be most prevalent in shallow water with low flow and common to abundant aquatic macrophytes. Harkness and Dymond (1961) stated that sturgeon were caught primarily over mud substrates. This appears to be the reverse of conditions in the Kenogami River. In future studies, if more emphasis is placed on relating sturgeon population densities to water velocities and substrate, perhaps gross predictive yield models could be developed. This could be extremely important when extrapolating data from one area to another.

The shorthead redhorse and the lake sturgeon appeared to be almost mutually exclusive in the Kenogami River. If true, this could prove to be a valuable management tool, as potential sites for sturgeon fisheries could be evaluated on the basis of the presence or absence of shorthead redhorse in experimental net sets.

The sturgeon population in Kapeesawatan Lake would quickly be decimated if

any commercial exploitation took place. Even subsistence fishing would exert extreme pressure on this small population. Similarly, the population at Ogahalla is incapable of sustaining a fishery. The subsistence fishing conducted by natives may already exceed recruitment. Conversations with natives and hunt club owners in the area suggest that this population has declined in recent years.

As only one field season has been spent at Mammamattawa, no definitive statements on the impacts of exploitation are possible. Certain inferences may be made from the composition of the catch. Fish in excess of 100 cm in length were not well represented in this population. The larger size mesh did not catch larger fish, indicating that this portion of the population was reduced. Further data are required to determine if recruitment is sufficient to support the current or a higher level of exploitation.

CONCLUSIONS AND RECOMMENDATIONS

The Kenogami is a relatively small river, but it flows through three OMNR districts and parts of two regions before its confluence with the Albany River. It also lies within two OMNR fishing divisions (20, 25). Management of sturgeon should be considered on a watershed basis. Under the existing approach with two fishing divisions, it is possible for sturgeon stocks in the Kenogami River to be managed by opposing schemes. It is also possible that management of sturgeon in the Albany River may affect Kenogami River populations and vice versa. OMNR regions and districts with jurisdiction over the Albany system should work together to formulate a common sturgeon management program.

In order to better understand lake sturgeon population dynamics and make rational management decisions, a commitment to more long-term and holistic studies should be made. Due to the paucity of data, predictions of sustainable yield were not possible. In the interim, it is recommended that: no commercial or subsistence fishing for sturgeon be allowed at Kapeesawatan Lake; no commercial fishery for sturgeon be permitted at Ogahalla; and the subsistence fishery at Ogahalla and Mammamattawa be closely monitored.

ACKNOWLEDGEMENTS

I am indebted to J. Atkinson, M. Sobchuk, E. Armstrong and W. Cook of the Ontario Ministry of Natural Resources who initiated and funded this project. S. St- Jules of Hearst District granted permission to fish in the Mammamattawa area and provided advice and field assistance. J. F. Tost of J.F. Tost and Associates aged the 1985 sample. S. Aubrey, J. Ferris, W. Him, B. W. Goodings, C. Reuben, T. R. Rhodes, G. Shantz, T. K. Sowden and J. Taylor assisted in the field.

REFERENCES

BAKER, J. P. 1980. The distribution, ecology, and management of the lake sturgeon (*Acipenser fulvescens* Rafinesque) in Michigan. Mich. Dep. Nat. Resour., Fish. Div., Fish. Res. Rep. No. 1883. 95 p.

CUERRIER, J.-P. 1966. L'esturgeon de lac *Acipenser fulvescens* Raf. de la rêgion du lac St. Pierre au cours de la pêriode du frai. Nat. Can. 93: 279-334.

DADSWELL, M.J. 1979. Biology and population characteristics of the shortnose sturgeon, *Acipenser brevirostrum* Le Sueur 1818 (Osteichthyes: Acipenseridae) in the Saint John River estuary, New Brunswick, Canada. Can. J. Zool. 57:2186-2210.

HARKNESS, W. J. K., and J. R. DYMOND. 1961. The lake sturgeon. The history of its fishery and problems of conservation. Ont. Dep. Lands Forests, Fish. Wildl. Br. 121 p.

JOLLIFF, T. M., and T. H. ECKERT. 1971. Evaluation of present and potential sturgeon fisheries of the St. Lawrence River and adjacent waters. N.Y. Dep. Environ. Conserv., Cape Vincent Fish. Sta. 113 p.

MacRITCHIE, I. 1981. Towards a river fish productivity estimator: the Frederick House River experience. Ont. Min. Nat. Resour., Cochrane Dist. Ms Rep. 15 p.

MAGNIN, E. 1977. Croissance, régime alementaire et fécondité des esturgeons, *Acipenser fulvescens*, du bassin hydrographique de la Grande Rivière (Québec). Nat. Can. 104: 419-427.

MAGNIN, E., et P. P. HARPER. 1970. La nourriture des esturgeons *Acipenser fulvescens* de la rivière Nottaway, tributaire de la baie James. Nat. Can. 97:73-85.

MOREAU, G., et L. LEGENDRE. 1979. Relation entre habitat et peuplements de poissons: essai de définition d'une methode numérique pour des rivières nordiques. Hydrobiologia 67:81-87.

PRIEGEL, G. R., and T. L. WIRTH. 1971. The lake sturgeon, its life history, ecology and management. Wis. Dep. Nat. Resour. Publ. 240-70. 20 p.

PRIEGEL, G. R., and T. L. WIRTH. 1975. Lake sturgeon harvest, growth, and recruitment in Lake Winnebago, Wisconsin. Wis. Dep. Nat. Resour. Tech. Bull. 83. 25 p.

PROBST, R. T., and E. L. COOPER. 1955. Age, growth, and production of the lake sturgeon (*Acipenser fulvescens*) in the Lake Winnebago region, Wisconsin. Trans. Am. Fish. Soc. 84: 207-227.

RICKER, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191. 382 p.

ROBSON, D. S., and H. A. REGIER. 1964. Sample size in Petersen mark-recapture experiments. Trans. Am. Fish. Soc. 93:215-226.

SCOTT, W. B., and E. J. CROSSMAN. 1973. Freshwater fishes of Canada. Fish. Res. Board Can. Bull. 184. 966 p.

SEMAKULA, S.N., and P. A. LARKIN. 1968. Age, growth, food, and yield of the white sturgeon (*Acipenser transmontanus*) of the Fraser River, British Columbia. J. Fish. Res. Board Can. 25:2589-2602.

THREADER, R. W. 1981. Age, growth and proposed management of the lake sturgeon (*Acipenser fulvescens*) in the Hudson Bay lowland. Ont. Min. Nat. Resour., Moosonee Dist. Ms Rep. 106 p.

BIOLOGY AND MANAGEMENT OF THE LAKE STURGEON IN THE MOOSE RIVER, ONTARIO[1,2]

R. W. Threader
52-2050 Upper Middle Road, Burlington, Ontario L7P 3R9

C. S. Brousseau
Ontario Ministry of Natural Resources, P.O. Box 3000, Cochrane, Ontario P0L 1C0

The age and growth of lake sturgeons (*Acipenser fulvescens*) were investigated in the lower Moose River system in the Hudson Bay lowland. The effects of current fishing methods also were reviewed in order to recommend procedures for a sustained-yield fishery. The population estimate of lake sturgeon in the study area was 7,088 with 95% confidence limits of 5,774-8,919. Sex ratios of all fish sampled throughout the summer were 1:1 and the length-weight relationship showed allometric growth with no significant differences between sexes. The age of first spawn for females was approximately 20 years but that for males was suspect due to small sample sizes of ripe males. Tissue mercury analyses showed relatively high levels of mercury in lake sturgeons longer than 102 cm. Growth was calculated from the Brody-Bertalanffy relationship that was employed in the Beverton-Holt yield model. This model indicated that increases in fishing intensity under present fisheries regulations would result in overexploitation. An alternative commercial fishery management plan for sustained yield is proposed.

[1]From the North American Journal of Fisheries Management 6: 383-390, 1986.

[2]Abstract reprinted with permission of the North American Journal of Fisheries Management.

THE LAKE STURGEON (*ACIPENSER FULVESCENS*) FISHERY OF LAKE OF THE WOODS, ONTARIO

T. Mosindy
Ontario Ministry of Natural Resources, Lake of the Woods Fisheries Assessment Unit, 808 Robertson Street, Kenora, Ontario P9N 3X9

The rapid decline of lake sturgeon (*Acipenser fulvescens*) populations in Lake of the Woods at the turn of the century was primarily due to overexploitation by a largely unregulated commercial fishery. The loss of spawning habitat in the Rainy River and its tributaries resulting from paper mill construction at Fort Frances - International Falls and agricultural development within the basin were contributing factors in the later stages. Recent increases in the annual commercial harvest, catch-per-unit-effort, and in numbers of sub-legal fish showing up in the fishery provide evidence that lake sturgeon are making a gradual recovery in response to improvements in the water quality of the Rainy River. However, mounting pressure from local fishermen for increased catch quotas for sturgeon may not be compatible with management attempts to rebuild brood stock numbers, given that the majority of sturgeon in recent commercial fish samples were immature.

INTRODUCTION

This paper presents a case history of the commercial fishery for the lake sturgeon (*Acipenser fulvescens*) on Lake of the Woods, Ontario. It addresses several factors which are suspect in the rapid decline of this fishery in its early stages and, in view of a perceived recovery, some of the problems associated with its present management.

THE STUDY AREA

Lake of the Woods is located at the junction of the borders of Ontario, Manitoba and the state of Minnesota. Two-thirds of its total surface area of 385,000 ha is in Canada (Fig. 1). The Rainy River which enters at the extreme southeast corner is the major inflowing tributary. Lake water flows out through the Winnipeg River and has been controlled by dams at the major outlets near Kenora since 1894. Annual water level fluctuations are kept to within 0.9-1.2 m.

Overall, Lake of the Woods is a relatively shallow, mesotrophic lake. It has a morphoedaphic index (Ryder 1965) of 10.5, based on average values of 83 mg L^{-1} for total dissolved solids (TDS) and 7.9 m for mean depth.

While the entire lake lies on the Precambrian Shield, the southern portion is underlain by old lake sediments deposited by glacial Lake Agassiz (Schwartz and Thiel 1963). As a result, these waters are shallower, more turbid and are considerably more productive than most of the lake, with a calculated MEI of 18.6, a mean depth of 7.4 m and TDS of 138 mg L^{-1}. Although lake sturgeon have been caught throughout the lake, this area is the focus of past and present sturgeon fishing activity on Lake of the Woods.

MATERIALS AND METHODS

Historical information was summarized from government catch records, early fisheries surveys and from conversations with veteran fishermen and other observers on Lake of the Woods. Current catch samples were obtained from the two most important existing sturgeon fisheries, located on lots 47 and 57 near the mouth of the Rainy River (Fig. 1). Ages were interpreted from sections of marginal pectoral fin rays of sampled sturgeon according to procedures outlined by Cuerrier (1951).

Fig. 1. Lake of the Woods, showing the location of fishing lots 47 and 57.

RESULTS AND DISCUSSION

THE PAST FISHERY

The development of the lake sturgeon fishery on Lake of the Woods followed roughly the same pattern on both American and Canadian sides. Commercial fishing had begun by 1888 on the Minnesota side and by 1892 in Ontario waters. Lake sturgeon and lake whitefish (*Coregonus clupeaformis*) were the target species of these early fisheries which were located around the southern end of the lake. The majority of sturgeon fishing was done with large pound nets which were set in 3.0 to 9.0 m of water off the shorelines around the Big Traverse in Minnesota, Buffalo Bay in Manitoba (Fig. 1), and along the southeast shore and about Big and Bigsby Islands in Ontario (Evermann and Latimer 1910). These nets were usually fitted with mesh measuring 20.3 cm on the lead, 11.4 cm in the heart and 8.9 cm in the crib. Sturgeon were also caught using unbaited set lines. This method was used primarily in the Rainy River and at its mouth (P. O'Connor, commercial fisherman, Rainy River, Ont. POW ILO, pers. comm.).

No gear restrictions, other than a prohibition on the use of gill nets, governed the American fishery until 1895

when regulations limiting each licencee to fish a maximum of 50 pound nets were introduced. This was reduced to 25 pound nets in 1911 and six per licence in 1925 (Schupp and Macins 1977). Gill nets were permitted in Minnesota waters in 1911. The Canadian fishery was restricted from the start to one pound net and 914 m of gill net per licence holder. This was later increased to five pound nets per licencee in response to fluctuations in the catch.

The fishery developed rapidly on both sides of the lake, although the American fishery consistently accounted for over two-thirds of the total sturgeon catch in most years during the period 1892-1910 (Fig. 2). Substantial quantities of caviar and swim bladders for the manufacture of isinglass were also marketed. Sturgeon harvests peaked at 809,600 kg in 1893 and 806,000 kg in 1895. The 1895 catch of 245,265 kg from the Canadian waters of Lake of the Woods represented 39% of the total sturgeon production for Ontario in that year (Harkness and Dymond 1961). A drastic decline in sturgeon harvests in both American and Canadian fisheries followed. Within a decade (1893-1903), total annual catches from the lake had fallen by over 95%. Annual harvests continued to decline to the point that a sturgeon fishery was virtually non-existent by the 1930s.

REASONS FOR THE DECLINE

It was recognized early in this century, that the collapse of the sturgeon fishery in Lake of the Woods was chiefly due to overfishing. The International Fisheries Commission had suggested that all sturgeon fishing in this area be curtailed for a period of four years to allow stocks to rebuild (Evermann and Latimer 1910), but this recommendation was not implemented. The rapidity and magnitude of the decline of this sturgeon population is evidence of the effects of a largely unregulated fishery on the large unexploited standing stock which was present in Lake of the Woods. Over 300 pound nets were in use and catches had peaked by the time

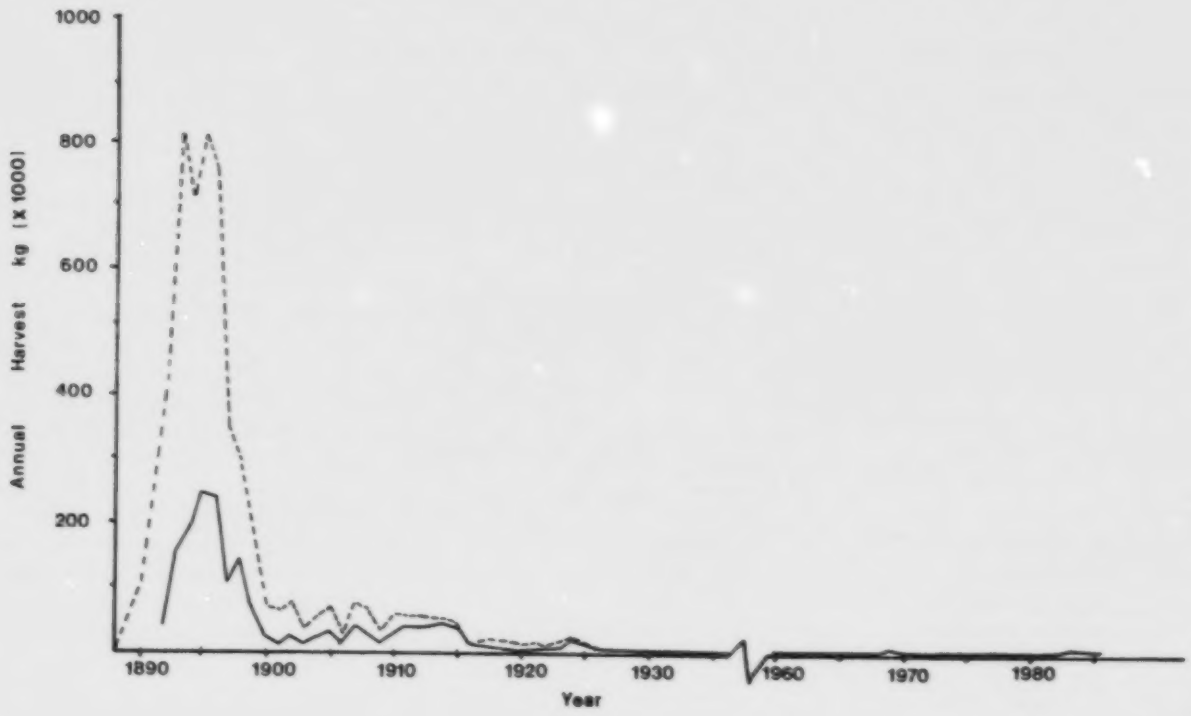

Fig. 2. Trends in the total annual harvest and the annual Ontario harvest of lake sturgeon from Lake of the Woods for the period 1888-1985. The dotted line represents the total annual harvest from both Minnesota and Ontario and the solid line represents only the annual harvest of sturgeon from the Ontario waters of Lake of the Woods.

restrictions on the maximum number of nets per licencee were introduced on the American side in 1895. A lack of minimum size regulations provided no protection for immature segments of the population which were fully vulnerable to the type of pound nets used. Continued fishing pressure following the initial collapse prevented any chance of stock recovery. A reduction in numbers of mature females in the population is supported by a decline in the percentage contribution of caviar in the total reported catch; from about 7% during the initial buildup of the fishery (1888-1895) to less than 1% in the years after 1906 (Evermann and Latimer 1910).

Although the decline of the lake sturgeon population preceded major industrial and agricultural development in the Rainy River basin, the resulting loss of spawning habitat in this river and its tributaries was probably a contributing factor in the later stages of their decline (Carlander 1949; Macins 1972). The principal spawning ground was reported to be the Long Sault Rapids (Eddy and Surber 1943), which is located on the Rainy River about halfway between Fort Frances-International Falls and the river mouth (Fig. 1). Sturgeon were also thought to have spawned near the Manitou Rapids and below International Falls on the Rainy River, in addition to sites on several of the larger tributaries such as the Sturgeon and the Big and Little Fork rivers (V. Macins, Ontario Ministry of Natural Resources (OMNR), Kenora, Ont. P9N 3X9, pers. comm.).

A hydroelectric dam was constructed at the outlet of Rainy Lake at the Rainy River in 1909 and pulp and paper mills were built at International Falls in 1907 and Fort Frances in 1914. All wood fibre and most chemical wastes from these mills were discharged directly into the Rainy River until the early 1970s. These wastes accumulated on the river substrate over time, especially in areas of slow current and have been found at various sites, including known spawning grounds, throughout the river's entire length and out into the lake at the river's mouth (Schupp and Macins 1977). The adverse effects of these wastes on the survival of walleye (*Stizostedion vitreum vitreum*) eggs and fry at major spawning sites in the Rainy River have been well documented (Smith and Kramer 1963; Colby and Smith 1967) and it is suspected that their effect on the successful reproduction of sturgeon in this river has been equally detrimental. The loss of Rainy River spawning sites has also been implicated in the reduction of longnose sucker (*Catostomus catostomus*) and lake whitefish populations in the southern part of Lake of the Woods (Schupp and Macins 1977).

Agricultural development along both sides of the Rainy River began before the turn of the last century and has continued into recent times. This has involved extensive land clearing, road building and ditching to improve drainage in low-lying areas. The net effect of these practices has been to increase runoff and incur problems associated with soil erosion. Siltation has probably had its greatest impact on sturgeon spawning sites located on the tributaries of the Rainy River.

THE PRESENT FISHERY

Although lake sturgeon have not been reported in the commercial catch from Minnesota waters since 1950, a commercial fishery for sturgeon continues to exist on the Ontario side of Lake of the Woods. It is centered around the mouth of the Rainy River at the extreme southeast corner of the lake. Sturgeon are regularly caught as far north as the Basil Channel between Big and Bigsby Islands and along the southeast mainland shore to Morson (Fig. 1). However, the majority of the present catch comes from fishing lots 47 and 57 which are located immediately adjacent to the river mouth and from a native fishery located at the Manitou Rapids on the Rainy River. Fish caught in the river are considered to be part of the same population as those in the lake (M. Sobchuk, OMNR, Fort Frances, Ont. P9A 1J4, pers. comm.).

Pound nets are no longer fished on the Ontario side of the lake. Most sturgeon are caught in multifilament nylon gill nets, comprised of 30.5 cm mesh (stretched measure) which is the minimum allowable mesh size for this fishery. Fishermen licenced for sturgeon are restricted to a maximum of 1,850 m of net. Sturgeon are oc-

casionally caught in regular commercial gill nets fitted with 10.8 cm mesh. The commercial sturgeon fishery on Lake of the Woods is also regulated by a fishing season which runs from July 1 to May 13 and by minimum size limits. The latter regulation restricts the commercial sale of sturgeon to fish greater than 63 cm in length, not dressed and 58 cm in length, dressed, according to measurements specified in the Ontario Fishery Regulations. Since 1984, the total annual sturgeon quota for the Ontario portion of the lake has been 4,545 kg, which is apportioned among ten individual fishermen. The Rainy River fishery has an annual quota of 1,275 kg.

Sturgeon never completely disappeared from the Ontario commercial catch from Lake of the Woods, but annual harvests remained well below 1,000 kg after 1925. During the most recent period (1964-1985), the commercial catch from the lake has averaged about 2,500 kg yr^{-1}, although it has shown considerable fluctuation, ranging from 106 kg in 1965 to 9,530 kg in 1983 (Fig. 3). Harvests rose sharply from 1978 to 1983, but have been limited by catch quotas since 1984. Annual reported catches from the Rainy River averaged 275 kg yr^{-1} from 1974-80, but increased to over 1,200 kg yr^{-1} during 1983-85.

Recent increases in the annual harvest of sturgeon from Lake of the Woods and the Rainy River have been accompanied by improvements in the catch-per-unit-effort (CUE) from sturgeon nets (Fig. 3). Changes in the CUE have preceded similar fluctuations in catch by at least one year during the interval 1969-85. A relatively high and sustained CUE since 1980 would appear to support the contention of commercial fishermen that sturgeon abundance is increasing and stocks are gradually recovering. Local fishermen have also observed an increase in the number of sub-legal fish caught in 10.8 cm mesh gill nets set near the mouth of the Rainy River. Several of these fish which were sampled in 1985 measured between 75-90 cm, total length (TL) and were aged at 5-7 years old. This pro-

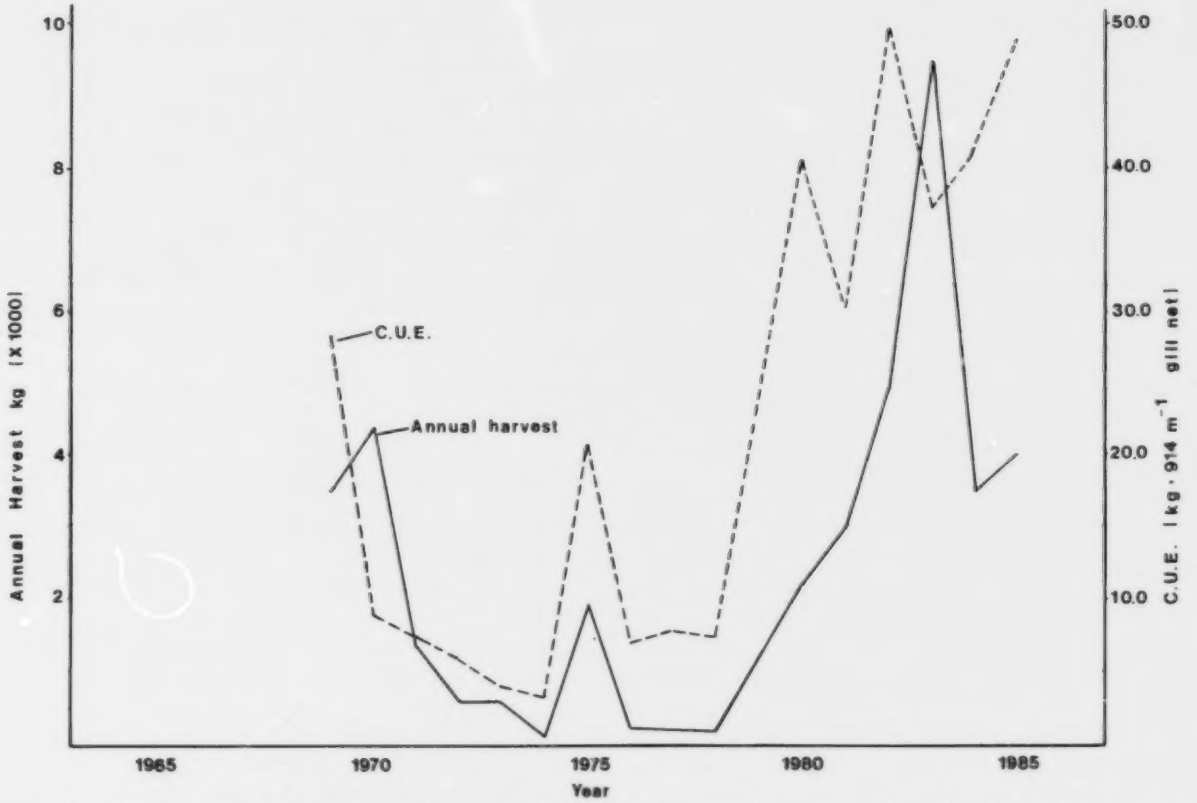

Fig. 3. A comparison of annual harvest (kg) and catch-per-unit-effort, expressed as kg 914 m^{-1} of sturgeon gill net (30.5 cm mesh), for sturgeon caught by the commercial fishery in Lake of the Woods, Ontario, during the period 1969-85.

vides some evidence that improvements in the water quality of the Rainy River have had a direct impact on the success of sturgeon reproduction in recent years. The amount of suspended solids, primarily wood fibre and other effluents with a high biological oxygen demand which are released into the river from pulp and paper mills at Fort Frances and International Falls have been significantly reduced since 1970-71 (J. Barr, Ontario Ministry of the Environment, Kenora, Ont. P9N 3X9 pers. comm.).

The age and size composition of sturgeon from the 1985 commercial catch indicates that the majority of the catch is comprised of fish which are just recruiting to the gear. The fish sampled averaged 127.9 cm (TL), 14.1 kg in weight and 20.4 years of age. Most ranged in size between 115 and 140 cm (Fig. 4) and were 17-26 years of age (Fig. 5). Fish larger than 140 cm in length and older than 26 years of age formed less than 15% of the sample. Males which averaged 123.6 cm (TL), 13.5 kg in weight and 19.3 years of age were generally younger and smaller than females in the sample ($\bar{x}$ = 128.8 cm (TL), 14.5 kg and 22.2 years old). The oldest fish aged was a 31 year old female.

When compared to mean length-at-age data from other areas (Fig. 6), Lake of the Woods sturgeon are much faster growing than several other populations in northern Ontario, such as Lake Nipigon (Harkness 1923), the Kenogami (Sandilands 1987), the Moose (Threader 1981) and the Groundhog and Mattagami rivers (Nowak and Jessop 1987). They grow slightly faster than sturgeon from Lake Nipissing (Love 1972) and exhibit growth rates which are similar to those

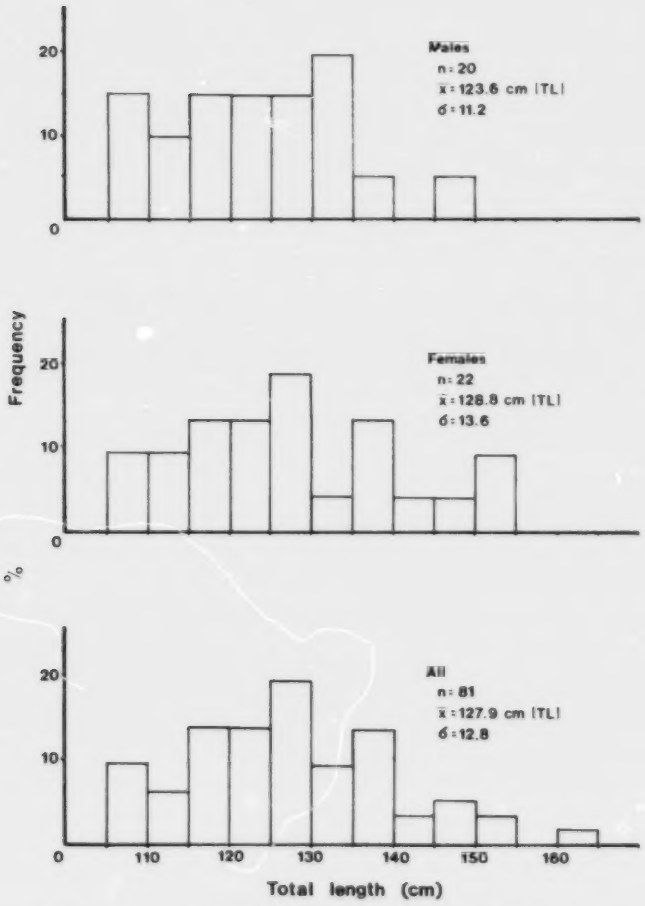

Fig. 4. Length-frequency distribution for lake sturgeon from the commercial catch during July-August 1985, Lake of the Woods, Ontario.

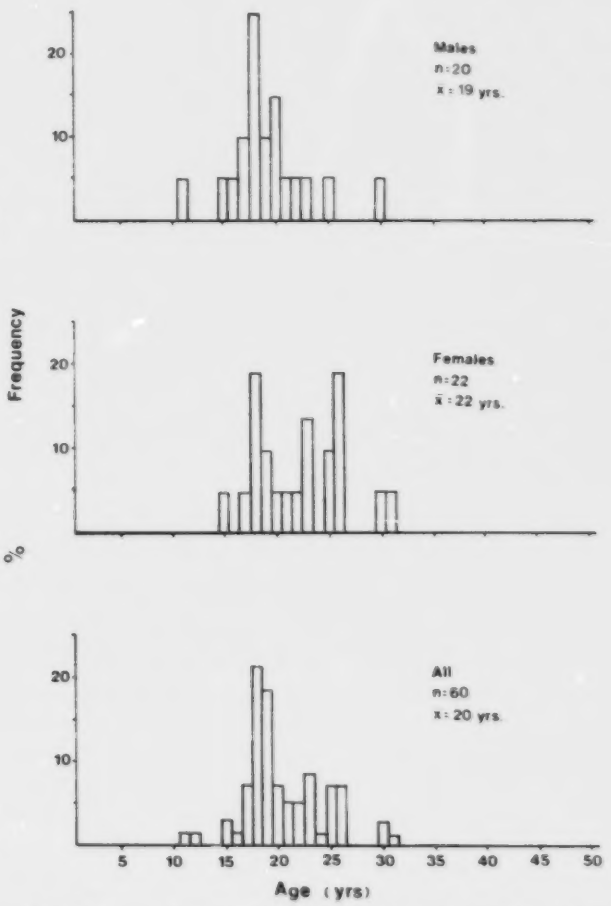

Fig. 5. Age-frequency distribution for lake sturgeon from the commercial catch during July-August 1985, Lake of the Woods, Ontario.

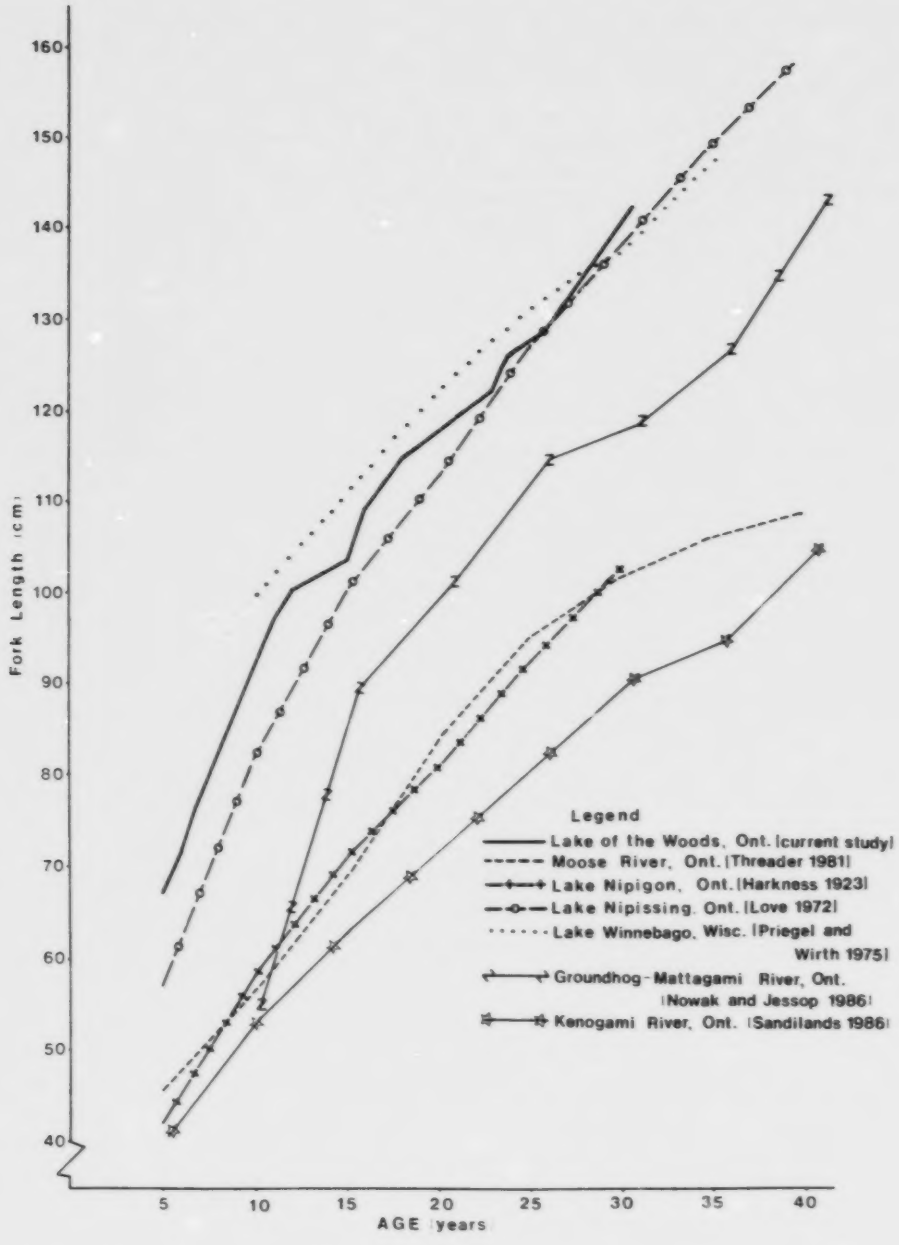

Fig. 6. A comparison of fork length (cm)-at-age for populations of lake sturgeon from various waters including Lake of the Woods, Ontario.

reported for lake sturgeon in Lake Winnebago, Wisconsin (Priegel and Wirth 1975).

The age and size at which sturgeon become sexually mature in Lake of the Woods is not known. This information could not be determined from the limited catch sample in 1985. Therefore, it was assumed that maturity rates for this population reflect the average for this species, although the fast growth of Lake of the Woods sturgeon may result in much earlier maturity. Based on mean ages at first maturity of 20 years for males and 25 years for females (Scott and Crossman 1973), more than 60% of males and 65% of females sampled from the commercial catch would be immature.

MANAGEMENT IMPLICATIONS

In view of a perceived increase in the abundance of legal-sized fish, the

Ontario Ministry of Natural Resources has come under increasing pressure from local commercial fishermen to raise catch quotas for sturgeon on Lake of the Woods and the Rainy River. The management of this fishery presents particular difficulties given the unique biology of the lake sturgeon; especially its late age to maturity.

Catch quotas for Lake of the Woods sturgeon were introduced in 1984 under the provincial government's policy for the modernization of the commercial fishery (OMNR 1982). The original quota (2,500 kg yr^{-1}) was based on the long-term (1964-83) average harvest for the lake. It was later raised to just over 4,500 kg yr^{-1} to reflect improvements in the fishery during recent years (1979-83). At the time, this quota appeared to be conservative, especially when compared to a reported commercial catch of 9,530 kg in 1983. Recent data, based on a sample from the 1985 commercial catch, suggests that this level of harvest may not provide adequate escapement to allow stocks to rebuild, especially under existing minimum size limits and gear restrictions.

A high fishing mortality of immature sturgeon may not be compatible with attempts to manage this species through a prolonged recovery period. Instead, steps to protect potential spawners and to maximize numbers of mature fish would be a more logical approach to rehabilitate this stock. Changes in existing regulations to increase mesh size of gear and the minimum legal length of fish could provide a larger buffer for potential spawners. However, it is recommended that the relationship of age and size to maturity and the periodicity of spawning for mature fish be determined for this sturgeon population before such changes are made. Barring a complete moratorium on sturgeon fishing in the Rainy River and Lake of the Woods, a reduction in annual catch quotas from present levels may be the only short-term option available to insure the survival of increased numbers of brood stock on which the recovery of this once productive fishery depends.

ACKNOWLEDGEMENTS

I wish to thank the following members of the Lake of the Woods Fisheries Assessment Unit for their help in preparing this report: Joan LeCain for typing various drafts of the report; Scott Lockhart for assistance in fish aging and drafting figures; and Allan Wilkinson for aging fish tissues. I am also grateful to Robert F. Kreger and Ronald O'Connor for providing sturgeon samples from their commercial catch.

REFERENCES

CARLANDER, K. D. 1949. Some trends in the commercial fisheries of Lake of the Woods, Minnesota. Trans. Am. Fish. Soc. 77:13-25.

COLBY, P. J., and L. L. SMITH, Jr. 1967. Survival of walleye eggs and fry on paper fiber sludge deposits in Rainy River, Minnesota. Trans. Am. Fish. Soc. 96:278-296.

CUERRIER, J.-P. 1951. The use of pectoral fin rays for determining age of sturgeon and other species of fish. Can. Fish Cult. 11:10-18.

EDDY, S., and T. SURBER. 1943. Northern fishes. Univ. Minn. Press, St. Paul, MN. 276 p.

EVERMANN, B. W., and H. B. LATIMER. 1910. The fishes of the Lake of the Woods and connecting waters. Proc. U.S. Natl. Mus. 39:121-126.

HARKNESS, W. J. K. 1923. The rate of growth and the food of the lake sturgeon (*Acipenser rubicundus* LeSueur). Univ. Toronto Stud., Biol. Ser. No. 24. Publ. Ont. Fish. Res. Lab. 18: 15-42.

HARKNESS, W. J. K., and J. R. DYMOND. 1961. The lake sturgeon. The history of its fishery and problems of conservation. Ont. Dep. Lands Forests, Fish Wildl. Br., Toronto. 121 p.

LOVE, G. F. 1972. The lake sturgeon (*Acipenser fulvescens*) of Lake Nipissing - 1971 study. Ont. Dep. Lands Forests, North Bay Dist. Ms Rep. 30 p.

MACINS, V. 1972. The fisheries of Lake of the Woods. Ont. Min. Nat. Resour., Sport Fish. Br., Toronto. 44 p.

NOWAK, A., and C. JESSOP. 1987. Biology and management of the lake sturgeon (*Acipenser fulvescens*) in the Groundhog and Mattagami rivers, Ontario, p. 20-32. *In* C.H. Olver [ed.] Proceedings of a workshop on the lake sturgeon (*Acipenser fulvescens*). Ont. Fish. Tech. Rep. Ser. No. 23. 99 p.

ONTARIO MINISTRY OF NATURAL RESOURCES. 1982. A report from the Committee on Modernizing Ontario's Commercial Fisheries. Fish. Br., Toronto. 15 p.

PRIEGEL, G. R., and T. L. WIRTH. 1975. Lake sturgeon harvest, growth, and recruitment in Lake Winnebago, Wisconsin. Wis. Dep. Nat. Resour. Tech. Bull. 83. 25 p.

RYDER, R. A. 1965. A method for estimating the potential fish production of north-temperate lakes. Trans. Am. Fish. Soc. 94:214-218.

SANDILANDS, A. P. 1987. Biology of the lake sturgeon (*Acipenser fulvescens*) in the Kenogami River, Ontario, p. 33-46. *In* C.H. Olver [ed.] Proceedings of a workshop on the lake sturgeon (*Acipenser fulvescens*). Ont. Fish. Tech. Rep. Ser. No. 23. 99 p.

SCHUPP, D. H., and V. MACINS. 1977. Trends in percid yields from Lake of the Woods, 1888-1973. J. Fish. Res. Board Can. 34:1784-1791.

SCHWARTZ, G. M., and G. A. THIEL. 1963. Minnesota's rocks and waters. Univ. Minn. Press, Minneapolis, MN. 366 p.

SCOTT, W. B., and E. J. CROSSMAN. 1973. Freshwater fishes of Canada. Fish. Res. Board Can. Bull. 184. 966 p.

SMITH, L. L., JR., and R. H. KRAMER. 1963. Survival of walleye eggs in relation to wood fibers and *Sphaerotilus natans* in the Rainy River, Minnesota. Trans. Am. Fish. Soc. 92:220-234.

THREADER, R. W. 1981. Age, growth, and proposed management of the lake sturgeon (*Acipenser fulvescens*) in the Hudson Bay lowland. Ont. Min. Nat. Resour., Moosonee Dist. Ms. Rep. 106 p.

BIOLOGY AND EXPLOITATION OF LAKE STURGEON (*ACIPENSER FULVESCENS*) IN THE QUEBEC WATERS OF THE SAINT-LAURENT RIVER

P. Dumont
Service de l'aménagement et de l'exploitation de la faune, Ministère du Loisir, de la Chasse et de la Pêche, Direction régionale de Montréal, 6255, 13e Avenue, Montréal, Québec H1X 3E6

R. Fortin and G. Desjardins
Département des Sciences biologiques, Université du Québec à Montréal, C.P. 8888, Montréal, Quebec H3C 3P8

M. Bernard
Service de l'aménagement et de l'exploitation de la faune, Ministère du Loisir, de la Chasse et de la Pêche, Direction régionale de Trois-Rivières, 5575, boulevard Saint-Joseph, Trois-Rivières, Québec G8Z 4L7

This report summarizes the results of data collected between 1981 and 1984 on the biology and commercial exploitation of lake sturgeon (*Acipenser fulvescens*) in the Québec waters of the Saint-Laurent River, from Lake Saint-François to Lake Saint-Pierre. Growth rate is relatively fast. The results of a mark-recapture experiment (741 recaptures/5,555 fish tagged) indicate that, with the exception of spawning migrations which seem rather extensive, movements are restricted. From Lake Saint-Louis to Lake Saint-Pierre, sturgeon probably form a single population; however, we noted local differences in the weight-length relation and harvest structure which are probably related to variations in environmental and exploitation factors. The Lake Saint-François fishery, which is isolated from the downstream fisheries by dams, is depleted. In all the commercial fishing sectors, natural and fishing mortality were estimated to be relatively high. In recent years, the annual legal commercial harvest was over 100 t. Yields are high, varying locally between 1.4 and 3.4 kg ha^{-1} and have probably been sustained for a long period of time. These high yields are probably related to the moderate biological productivity of the Saint-Laurent River waters; to the fact that large sectors are lightly exploited; and also to the high selectivity of the gill nets used by commercial fishermen. Effects of hypothetical changes in size limits on yield per recruit are considered.

Ce rapport trace la synthèse d'une analyse préliminaire des données récoltées entre 1981 et 1984 sur la biologie et l'exploitation commerciale de l'Esturgeon jaune (*Acipenser fulvescens*) dans les eaux québécoises du fleuve Saint-Laurent, du lac Saint-François au lac Saint-Pierre. La croissance est relativement rapide. Les résultats d'une campagne d'étiquetage (741 recaptures/5,555 poissons étiquetés) montrent que, sauf pour les migrations de fraye, qui semblent relativement importantes, les déplacements sont limités. Du lac Saint-Louis au lac Saint-Pierre, l'Esturgeon jaune ne forme probablement qu'une seule population. Cependant, nous avons également pu constater des différences locales dans la relation longueur-poids et dans la structure de la récolte; celles-ci peuvent être reliées à des différences au niveau de facteurs environnementaux et halieutiques. La population du lac Saint-François, isolée du reste du territoire à l'étude, est décimée. Pour tous les autres secteurs de pêche, nos estimations de la mortalité naturelle et par la pêche paraissent élevées. Au cours des dernières années, la récolte légale à la pêche commerciale a dépassé 100 t. Les rendements sont élevés; ils varient, selon le secteur, entre 1.4 et 3.4 kg/ha^{-1}. Ces rendements élevés sont probablement soutenus depuis plusieurs années; ils peuvent être expliqués par la productivité biologique modérément élevée du fleuve Saint-Laurent, par le maintien de vastes secteurs faiblement exploités et par l'utilisation, par les pêcheurs commerciaux, de filets très sélectifs. Les effets d'éventuels changements de la taille légale sur le rendement par recrue sont discutés.

INTRODUCTION

Since 1981, the Montréal and Trois-Rivières regional Wildlife Management Services of the Ministère du Loisir, de la Chasse et de la Pêche and the Department of Biological Sciences of the Université du Québec à Montréal have been involved in a study of lake sturgeon (*Acipenser fulvescens*) biology and exploitation in the Québec waters of the Saint-Laurent River. Our study was justified by an increasing demand for commercial fishing licences. In the past 40 years, different aspects of lake sturgeon biology in the Saint-Laurent River and in adjacent waters have been investigated. Growth (Cuerrier 1951; Cuerrier and Roussow 1951; Magnin 1962), reproduction (Cuerrier 1966), movements (Roussow 1955; Magnin and Beaulieu 1960) and exploitation (Cuerrier 1962) were studied. In the most recent study, Mongeau et al. (1982) described the natural restoration of sturgeon in Lake des Deux Montagnes following an anoxic period in the early 1950s. Information gathered on this particular group of young and immature fish could not be applied to other sectors.

Our main objectives were: 1. to characterize the commercial harvest; 2. to describe the movement patterns and evaluate the homogeneity of the sturgeon population(s); 3. to locate the spawning grounds; 4. to examine commercial and sport fishing regulations; and 5. to gather information useful to the protection and, in some parts of the study area, to the rehabilitation of lake sturgeon populations.

This paper summarizes the results of a preliminary analysis of the data gathered between 1981 and 1984 focusing on the commercial exploitation of sturgeon. A detailed analysis of all our data, including those collected in 1985, will be available before the end of the year (Dumont et al. in prep.).

STUDY AREA

The study area extends from the western part of Lake des Deux Montagnes, on the des Outaouais River, and Lake Saint-François to the eastern part of Lake Saint-Pierre, including Lake Saint-Louis and the Laprairie Basin, on the Saint-Laurent River (Fig. 1). This area forms a complex network of rivers, channels and islands. Brown waters representative of the Precambrian Shield are dominant along the northern shore, and green waters representative of the Great Lakes, along the southern shore.

The lakes in the study area are actually enlargements of the river in which the water current velocity is generally moderate. Except in the navigation channel, depth is usually less than 6 m. More than 90 fish species have been identified in the study area. Although it suffers a high degree of industrial and organic pollution, the study area remains productive for aquatic life because of its high dilution factor and the periodic presence of large rapids.

Commercial fishing occurs mostly in Lake Saint-Louis, the Laprairie Basin, the Sorel-Berthier Islands sector and Lake Saint-Pierre (Fig. 1). Algal and chlorophyll production are moderate in these sectors (Keighan 1977).

The lake sturgeon is also present downstream from our study area between the eastern part of Lake Saint-Pierre and the brackish water limits, where it shares its habitat with the Atlantic sturgeon (*A. oxyrhynchus*). The lake sturgeon commercial fishery is considered depleted in this area (G. Labrecque, Agriculture, Pêcheries et Alimentation Dept., Québec G1P 3W8, pers. comm.).

MATERIALS AND METHODS

Between 1981 and 1984, 5,555 lake sturgeon were tagged, weighed, measured (total length, legal length, fork length and maximum girth) and released. Most of these fish were longer than 750 mm. The tagging operation covered the whole study area, with the exception of Lake Saint-François, which is isolated from Lake Saint-Louis by a series of dams and locks (Fig. 2). Fishing pressure was not applied equally throughout the study area. Important and localized concentrations of sturgeon were fished more heavily. Most of the fish were caught with gill nets (mainly from 14 to 25.4

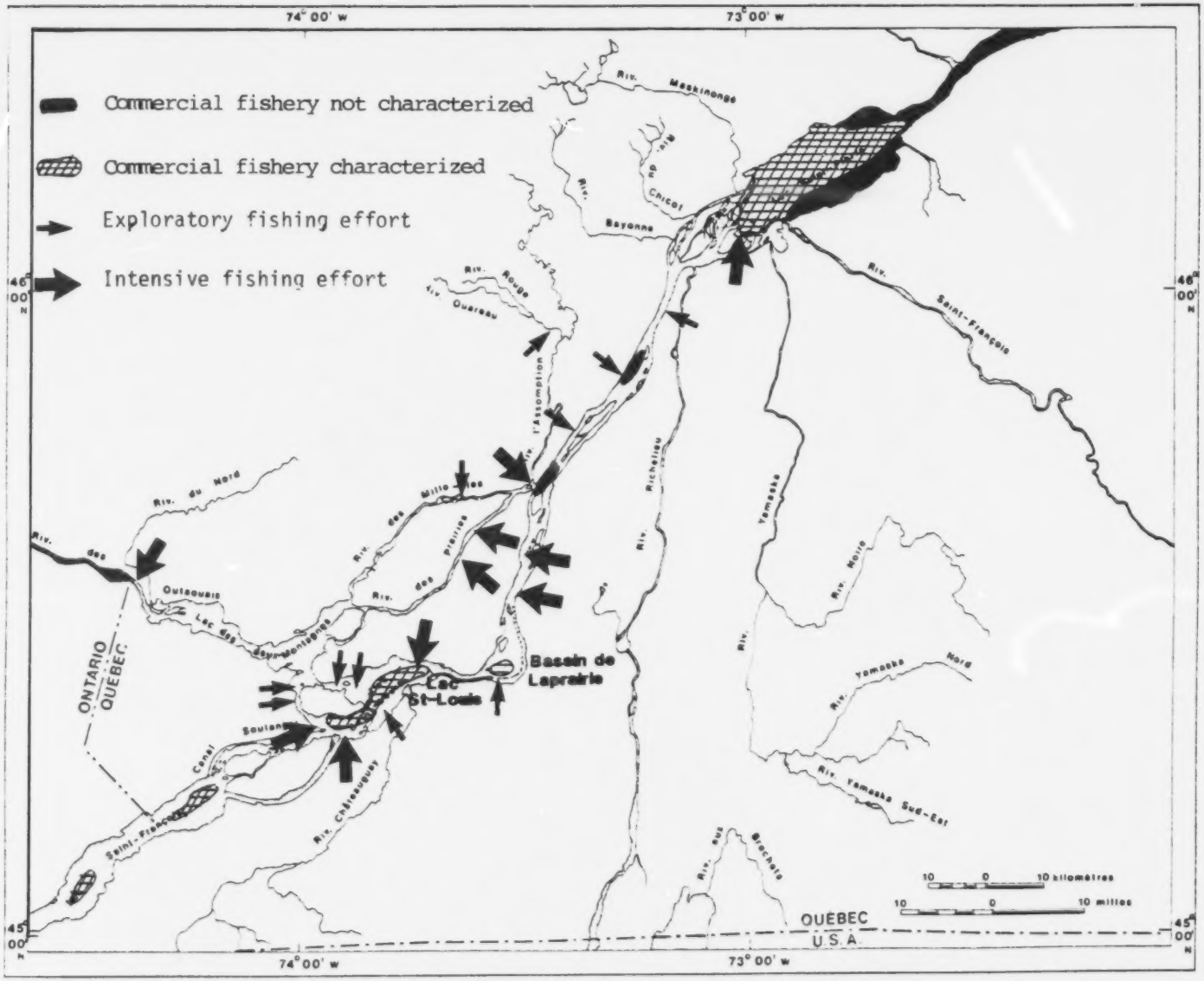

Fig. 1. Location of the study areas.

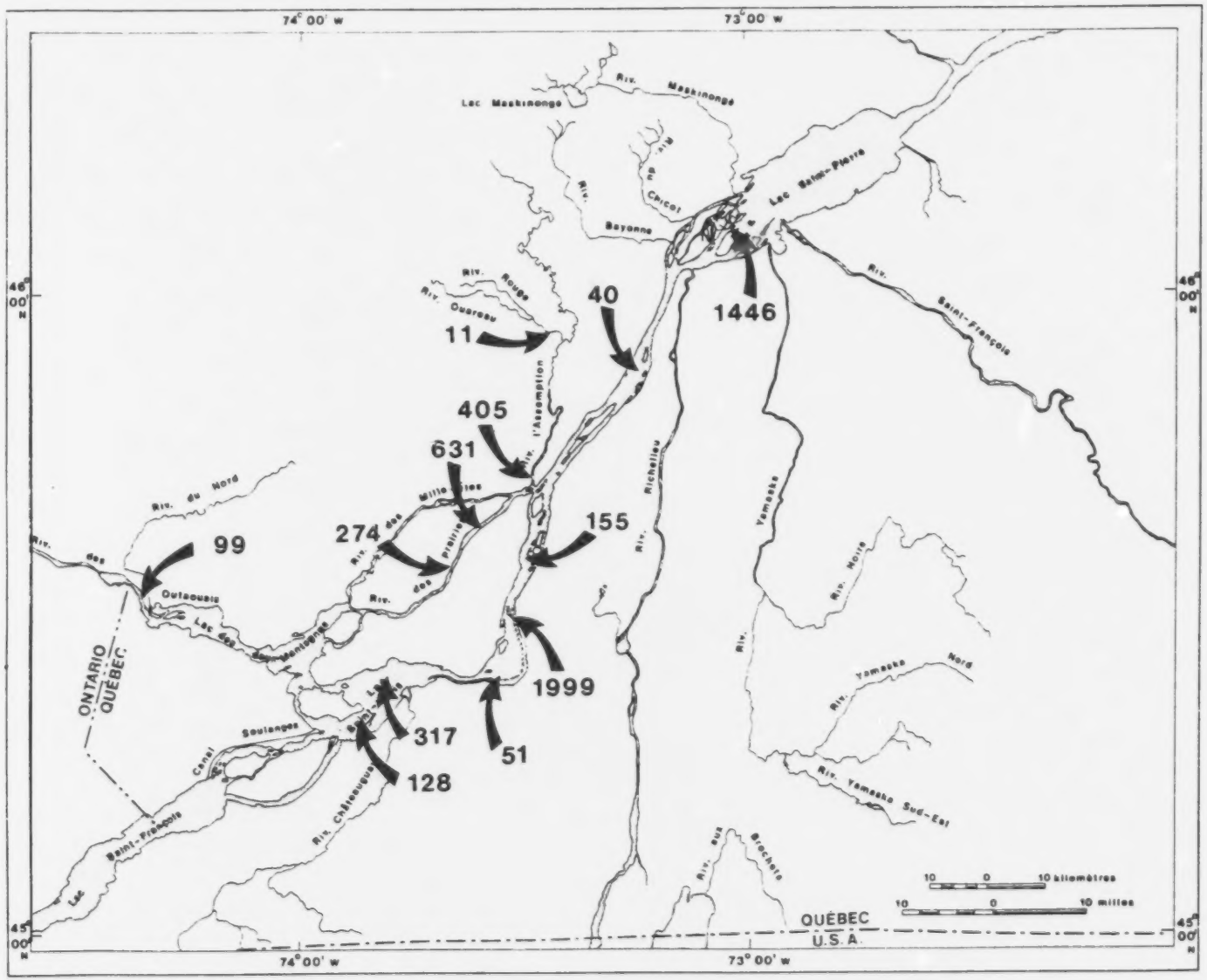

Fig. 2. Number of lake sturgeon tagged at different sites between 1981 and 1984.

cm, stretched measure). A limited number were caught by electrofishing. Spaghetti tags with a nylon or polyester anchoring filament were attached through the musculature at the base of the anterior part of the dorsal fin. Tagging operations were carried out mainly during the spring period. Since 1983, tag returns were enhanced by a five dollar reward offered to commercial fishermen. All commercial fishermen operating on the des Outaouais River and the Saint-Laurent River were contacted annually by phone and/or by letter, and those operating in the study area were visited regularly. Posters were placed near the main public sport fishing access sites (public wharves, outfitters, boat launching ramps).

Long-term harvest statistics, gathered by Le Bureau de la statistique de Québec, were not accurate. Therefore, the harvest was estimated for at least one year using a log book system in which catch was registered by number of sturgeon of different weight classes (<5.4; 5.4-9.1; 9.1-17.1 and >17.1 kg).

The catch was sampled in 1981 and 1982 in the upper part of the study area (Lake Saint-Louis and Laprairie Basin) and in 1984 in the lower part (Sorel-Berthier Islands and Lake Saint-Pierre). Sampling was generally conducted at the landing sites. Fish were measured and weighed; the sex was determined and the marginal ray of the pectoral fin was collected. The gonads were also collected on approximately 1,000 fish, but have not been examined yet. Some commercial fishermen also contributed by collecting pectoral fin rays for the age structure studies. These fish were not measured. Data were gathered on 3,694 specimens of which 2,710 were aged, using 450 to 500 µ marginal ray cross-sections. Subsampling was applied to larger local samples. Independent age determinations performed by two different readers coincided in 98.3% of the samples and differences never exceeded 4%. The age of the oldest fish was considered to be the mean of four determinations by two different readers (Dadswell 1979).

Historical data on sturgeon length distribution, collected in 1945 in the lower part of the study area by J.-P. Cuerrier (unpubl. data; see Cuerrier 1962) were transformed into an age distribution using an age-length class matrix. This matrix was based on length-at-age data for 996 sturgeon caught in 1984 in the same area.

We estimated indirect selectivity (Hamley 1975) of gill nets (15.2; 19.0; 20.3 and 25.4 cm mesh size) and longlines in relation to total fish length. Using recapture data of fish caught twice in the same gillnet mesh size, we estimated direct selectivity (Cucin and Regier 1966), which is based on the observed probability for a fish of a given length class caught in a given mesh size to be recaptured in the same mesh size. Sample sizes restricted these estimations to the mesh sizes used by commercial fishermen, which vary between 19.0 and 20.3 cm.

Total instantaneous mortality rates (Z) were calculated for this mesh size range, from data adjusted for gillnet selectivity, using the catch curve method (Ricker 1975). The same process was applied to the 1945 historical data.

RESULTS AND DISCUSSION

BIOLOGICAL ASPECTS

Growth and longevity

A preliminary growth curve, based on mean total length back-calculated at each annulus, was established using 255 specimens (304-1,717 mm) sampled from the main commercial fishing sectors, excluding Lake Saint-François (S. Leblanc and R. Fortin, Université du Québec à Montréal, unpubl. data.).

A von Bertalanffy equation was derived from these data:

$$L_t = 1{,}685[1-e^{-0.048(t+2.97)}] \qquad (1)$$

It over-estimates length at ages one and two but can be considered accurate for the next 38 age groups. Reference lengths at ages from this model are as follows: 420; 536; 781; 1,126; 1,339 and 1,470 mm, at ages 3, 5, 10, 20, 30 and 40, respectively (Fig. 3).

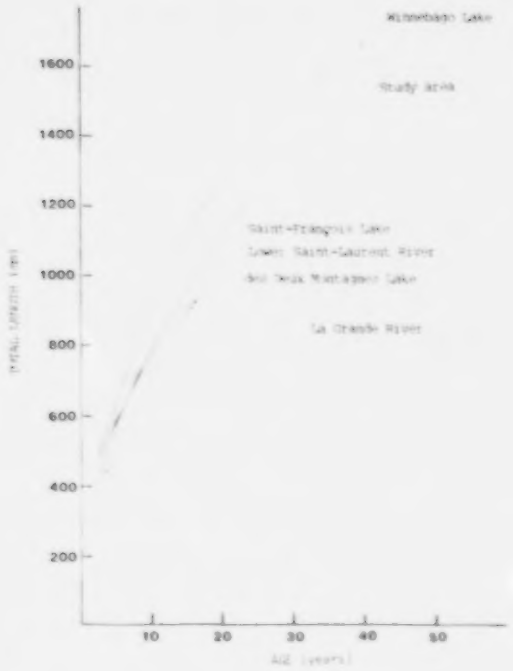

Fig. 3. Growth in length of lake sturgeon at various locations.

The sturgeon growth rate in our study area is lower than in Lake Winnebago, Wisconsin (Probst and Cooper 1954). It is similar to the Lake Saint-François population growth rate (Cuerrier and Roussow 1951), but higher than the rate observed in Lake des Deux Montagnes (Mongeau et al. 1982), in the lower part of the Saint-Laurent River near Québec City (Magnin 1962) and in the La Grande River in northern Québec (Magnin 1977).

The oldest sturgeon in our sample was 51 years old. It was 1,714 mm long and weighed 41 kg. Longevity is likely greater as we have unaged pectoral fin rays of fish weighing between 45 and 90 kg caught recently by commercial fishermen.

Females seem to live longer than males. In our 1984 commercial catch sample from the lower part of the study area, the sex ratio of sturgeon less than 1,500 mm was 1:1.12 (606 males, 676 females), which is not significantly different from 1:1 ($P > 0.05$). Fish larger than 1,500 mm were represented by only three females. Cuerrier (1945) noted a 1:1 sex ratio for sturgeon less than 1,500 mm (N = 510) and a 1:13 sex ratio for larger fish (N = 14) in his 1945 sample in the same area.

The weight-length relation does not appear to vary according to sex ($P > 0.05$) but shows local differences ($P < 0.05$). The equations for the upper and lower parts of the study area are, respectively:

$$\log W = -6.472 + 3.434 \log TL \quad (r = 0.93,\ N = 896) \qquad (2)$$

$$\log W = -5.725 + 3.179 \log TL \quad (r = 0.94;\ N = 1,507) \qquad (3)$$

Sexual maturity

Gonads were collected from more than 1,000 sturgeon. This material has not been examined yet, but we had the opportunity while tagging fish on or near spawning grounds, to sex 312 ripe sturgeon (307 males and 5 females). Fig. 4 shows that mature males are smaller on the Carillon spawning site in Lake des Deux Montagnes; it was mentioned earlier that this population is in a recovery stage. In Carillon, 89.9% of the males were longer than 1,000 mm

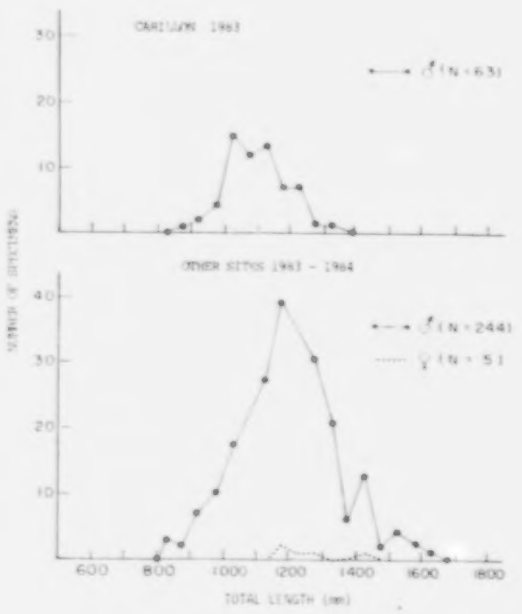

Fig. 4. Length distribution of running, ripe sturgeon caught and tagged on or near spawning grounds.

and 62% were longer than 1,100 mm. At the other sites, 93.4% of the males were longer than 1,000 mm (approximate age: 16) and 78.7% were longer than 1,100 mm (approximate age: 19). The smallest and largest spawning males were 803 and 1,640 mm long. Only five ripe females were captured and their total length varied between 1,169 and 1,406 mm. It is interesting to note that some immature sturgeon were caught on the spawning grounds. Cuerrier (1966) also noted the presence of immature sturgeon on a Saint-François River spawning ground.

It is widely recognized that lake sturgeon do not spawn each year. During our study, 12 sturgeon were tagged on the des Prairies River spawning grounds in 1983 and recaptured in 1984 at the same sites: two of these were males which were ripe both in 1983 and 1984, while one was a female which was classified as ripe in 1984. Wirth and Cline (1955) also observed that in Wisconsin, at least a few males can reproduce every year.

Movements

Out of 5,555 sturgeon tagged from 1981 to 1984, 678 were recaptured once; 56, twice; six, three times; and one, four times. Of these 741 recaptures, 455 were made by our group, 280 by commercial fishermen, five by sport fishermen and one was reported dead. The longest period between capture and recapture was 1,251 days. Mongeau et al. (1982) reported recaptures after 14 years from sturgeon tagged in 1964 and 1968; some of these fish were still being recaptured in 1985.

Of the 741 recaptures, 493 occurred on or near the tagging sites. If we only consider fish recaptured at least 30 days after tagging, this ratio becomes 241/447. Distances covered by sturgeon varied between 5 and 138 km. The mean distance was 37 km.

Previous tagging studies in the study area, based mainly on small immature fish, generally concluded that lake sturgeon are relatively sedentary (Roussow 1955; Magnin and Beaulieu 1960; Mongeau et al. 1982; Leclerc 1984). Because of unequal distribution of fishing pressure and periodicity, due to the fact that most of our tagging work was done during the spring, our results are difficult to interpret. They vary according to the nature of the tagging site as fish tagged on the spawning grounds show more lengthy movements. For example, fish tagged on the des Prairies River spawning grounds were recaptured in both the lower and upper part of the study area. At the present time, homing cannot be inferred from our data. However, homing has been observed in the Lake Winnebago - Wolfe River system, Wisconsin (Priegel and Wirth 1971): sturgeon leave Lake Winnebago to migrate 200 km up the Wolfe River, spawn with fish from other lakes and return to Lake Winnebago. A simila migration pattern might apply to the Saint-Laurent sturgeon. The fish may leave the lower and upper parts of the study area, spawn on the same spawning grounds, which are located approximately midway between Lake Saint-Louis and Lake Saint-Pierre, and then return to their respective areas after reproduction. This hypothesis needs to be verified by additional work on the spawning grounds.

Movement patterns are different for fish tagged outside the spawning areas. Between 1981 and 1984, tagged sturgeon showed a greater tendency to remain in their respective area than to move out: the sedentary to migrant ratios for the upper and lower parts were 69:7 and 151:15, respectively. Except for fish tagged on the spawning grounds, most sturgeon recaptured more than once were taken at or near the tagging sites (Table 1). These observations suggest that, except during the spawning migrations, movements are restricted and

Table 1. Number of recaptures on the tagging sites for sturgeon recaptured more than once. These data relate to fish tagged on sites which are not spawning grounds.

Sturgeon recaptured	No. of specimens	No. in the tagging site: Recaptures 1st	2nd	3rd	4th
2 times	40	40	35	-	-
3 times	4	4	4	3	-
4 times	1	1	1	1	0

are probably limited to small groups of fish. These findings need to be supported by long-term recapture data.

Stock homogeneity

Our results indicate that in the area which is commercially fished, lake sturgeon probably form a single stock. Recaptures of fish tagged on the spawning grounds are spread over the entire study area. Therefore, the lake sturgeon population in this area is probably a single genetic stock.

Genotypic homogeneity does not lead to phenotypic homogeneity since the weight-length relations differ. Moreover, except for spawning migrations, movements are limited. There is a stronger trend to downstream movement than upstream by sturgeon tagged toward the lower end of the study area, near the Sorel-Berthier Islands (39:15) and a stronger trend to an upstream movement than downstream for those tagged near Longueuil, in the upper section (48:24). Also, characteristics of the commercial harvest in the upper and lower sections differ significantly. This can be attributed at least in part to different exploitation rates. However, the commercial fishery, which is located mainly in both extremities of the study area (excluding Lake Saint-François), depends partly on contributions from other sectors (Table 2), indicating that some mixing occurs between groups of sturgeon living in various sections of this area.

These observations cannot be applied to Lake Saint-François, which is isolated from the rest of the study area, and to Lake des Deux Montagnes. An analysis of population structure and recaptures led Mongeau et al. (1982) to conclude that, in Lake des Deux Montagnes, sturgeon form an isolated stock. This conclusion has been strengthened by preliminary results of a complementary research program conducted during the fall of 1985, when 724 additional sturgeon were tagged. In spite of a considerable fishing effort (241 gillnet days), no sturgeon tagged outside of Lake des Deux Montagnes were recaptured (M. Rousseau, Service de l'aménagement et de l'exploitation de la faune, Montréal, unpubl. data).

Population aggregations

Observations of commercial fishing operations and our own field work indicate that, within the study area, lake sturgeon occur in large numbers at very localized or specific sites that form only a small part of the study area. Very few are caught outside these particular sites.

Curiously, some sturgeon seem to form very stable groups. On three occasions, pairs of fish were tagged simultaneously and recaptured together, one pair on the same site and the other two on another site. Dadswell (1979) made similar observations for *A. brevirostrum*.

Table 2. Distribution of recaptures by commercial fishermen. Fish were tagged and released at various fishing sectors.

	Recaptures which were tagged in		
Commercial fishing sectors	The same sector	Another sector	Total
Lake Saint-Pierre and Sorel-Berthier Islands	97	45	142
Lake Saint-Louis	54	49	103
Laprairie Basin	5	28	33
Total	156	122	278

THE STURGEON FISHERY

Harvest

Historical harvest data are inaccurate and commercial harvest data can only be considered trustworthy since 1983, when we initiated a log book system and increased personal contacts with the fishermen.

In 1983, more than 102.5 t were harvested, mainly in the Lake Saint-Pierre - Sorel-Berthier Islands sectors (49.1 t), in Lake Saint-Louis (40 t) and in the Laprairie Basin (9.3 t). To our knowledge, this represents the most important *Acipenseridae* fishery in North America. The commercial value of lake sturgeon is high. The species is sought after for its flesh, which is sold fresh or smoked, for its caviar, and even for its viscera which are used in the cosmetics industry.

The lake sturgeon does not receive much attention from sport fishermen in Québec. It is caught by a small number of specialists at a limited number of sites, or by accident. Between 1981 and 1984, five tags were returned by sport fishermen in comparison with 280 by commercial fishermen. Since the tag return rate is probably lower for the sport fishery, we estimated that the annual sport harvest for this activity does not exceed 5 to 10 t.

The illegal harvest cannot be estimated, but observations made during our field work, information from game wardens and discussions with poachers indicate that it is considerable. It seems to be a well organized activity which is mainly targeted on fish engaged in their spawning migrations or on the spawning grounds.

Present regulations

Sturgeon commercial fishing regulations include different components. Seasons, fishing gear and fishing sites are specified on the licence, which is issued annually. The number of licences issued in 1984 was six for Lake Saint-François, nine for Lake Saint-Louis, two for the Laprairie Basin, two for the Saint-Laurent River and 42 for the Sorel-Berthier Islands and Lake Saint-Pierre sectors.

A closed season was not established until 1969. Initially, it lasted from May 15 to June 14. In 1982, it was extended from April 1 or April 15, depending on the fishing sectors, to June 14. This was to ensure a greater protection for sturgeon migrating to their spawning grounds, or already present on these sites. This change was initiated because observations by Provost et al. (1982) showed that spawning occurs earlier than previously thought.

Three types of fishing gear are allowed: 1. gill nets with a minimum stretched measure of 19 cm; generally the mesh used does not exceed 20.3 cm; each fisherman is allowed to use between 100 and 200 meters of net; 2. longlines: the number of hooks is restricted, varying between 200 and 600; and 3. seines: in 1982, a special seine licence was issued for a limited area of the navigation channel in the sector located between the Laprairie Basin and the Sorel-Berthier Islands; it was not used.

Generally, fishing sites are specified on the licences in order to limit conflicts with the sport fishery.

Québec fishing regulations include a minimum length limit of 457 mm in the Saint-Laurent River. This legal length is measured from the posterior part of the gill aperture to the posterior part of dorsal fin, and is approximately equivalent to a total length of 800 mm.

Recreational fishing was not regulated until 1971, when a closed season was established (May 15 to June 14). This closed period was prolonged by one month in 1984; it now extends from April 15 to June 14. The daily bag limit is two fish and there is no length limit.

Gear selectivity

The shape and degree of asymmetry of the selectivity curves towards the larger fish sizes vary according to mesh size (Fig. 5); the range of maximum efficiency is wider for the larger mesh (25.4 cm).

The length distribution varies between sectors, between periods and between gears (Fig. 6). In the Sorel-Berthier Islands 1984 gillnet catch, sturgeon are generally smaller than in

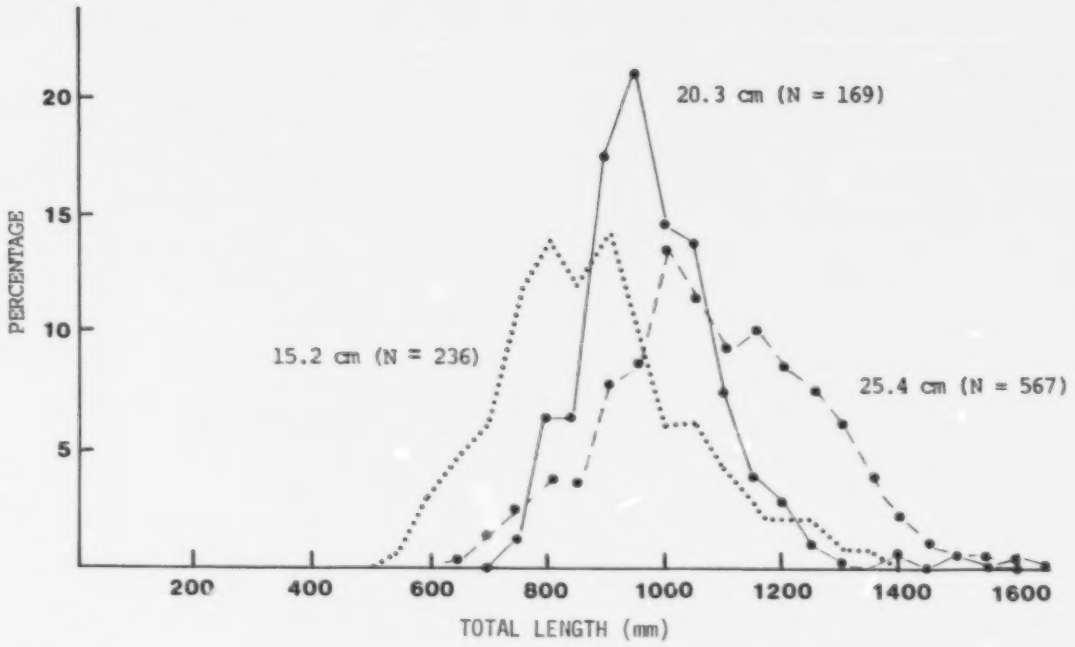

Fig. 5. Indirect selectivity of gill nets of various mesh sizes (stretched measure) for lake sturgeon at the Longueuil tagging site.

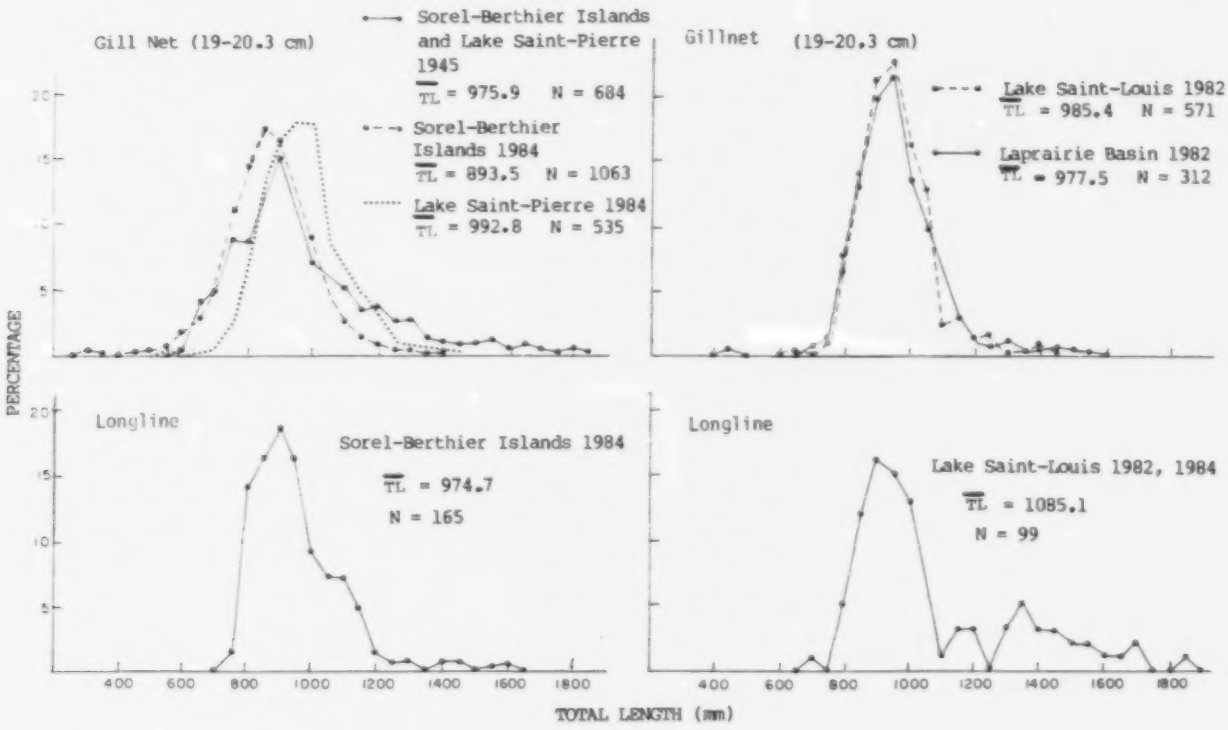

Fig. 6. Length distribution of sturgeon caught in commercial fishing gear in various sectors of the study area. The 1945 data for Sorel-Berthier and Lake Saint-Pierre sectors are from J.-P. Cuerrier (unpubl. data; see Cuerrier 1962).

all other catches represented. Lake Saint-Pierre, Laprairie Basin and Lake Saint-Louis gillnet catches are similar.

The longline and gillnet catches differ both in the Sorel-Berthier Islands sector and in Lake Saint-Louis. The length range selected by the longline is wider and the corresponding mean length is in the order of 100 mm higher. The same differences in the length range and mean length were observed between the longline catch in Lake Saint-Louis and in the Sorel-Berthier Islands. The latter differences could be related to seasonal variations in gear selectivity, since the longline is mostly used during February-March in Lake Saint-Louis and during June-July in the Sorel-Berthier Islands sector. Greater activity prior to the beginning of the spawning migration in winter or less aggressive behaviour in cold waters, resulting in fewer escapes from the hooks, could explain the larger size of Lake Saint-Louis fish. However, since the occurrence of large fish is lower both in the gillnet and in the longline catches from the Sorel-Berthier Islands sector, the differences are not artifacts and are probably related to differential mortality rates.

The gillnets used by the commercial fishermen are relatively selective. Smaller and larger fish are not caught with the same efficiency as those between 800 and 1,350 mm. Even for this size range, indirect estimates of selectivity do not reflect real selectivity. Since the length distribution is different from one sector to another, the indirect estimates are influenced by the abundance of fish of the different length classes in each sector. Using recapture data (N = 67), a preliminary direct estimate of selectivity was calculated for the 19.0 to 20.3 cm mesh size. We hope that additional recapture data collected in 1985 (N = ≈130) will help to refine this estimate. The direct selectivity curve (Fig. 7) shows two peaks: one for the 850-899 mm length class and another for the 1,150-1,199 mm length class. The first peak is probably related to the higher vulnerability of younger sturgeon, whose bony plates are still quite "spiny".

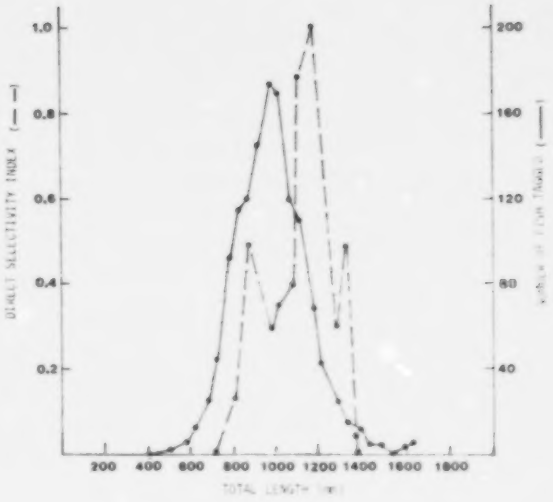

Fig. 7. Direct selectivity of the gillnets used by commercial fishermen in the study area (data pooled for the nets 19 to 20.3 cm, stretched measure). The number of fish tagged by size class is also indicated.

Mortality

Catch curves from the commercial fishery adjusted for gillnet selectivity (Fig. 8) yielded total annual mortality rate (A) estimates of 25.7% (ages 13 to 25) and of 32.7% (ages 13 to 25), respectively, for the Sorel-Berthier Islands sector in 1945 and in 1984. Estimates for Lake Saint-Pierre and Lake Saint-Louis were 27.2% (ages 16 to 27) and 28.1% (ages 13 to 27). Corresponding total instantaneous mortality rates (Z) were: 0.3, 0.4, 0.32 and 0.33.

For the 800-1,350 mm size class, the annual tag return rate varied between 1.3% and 9% (Table 3). Tag return rates vary between 2.2 and 3.3% for fish tagged in the Longueuil-Laprairie Basin sector. These fish were recaptured mainly in the upper part of the study area. The corresponding figure for fish tagged around the Sorel-Berthier Islands was 9%. These fish were recaptured mainly in the lower sectors.

Tag returns probably underestimate exploitation rates, since the illegal

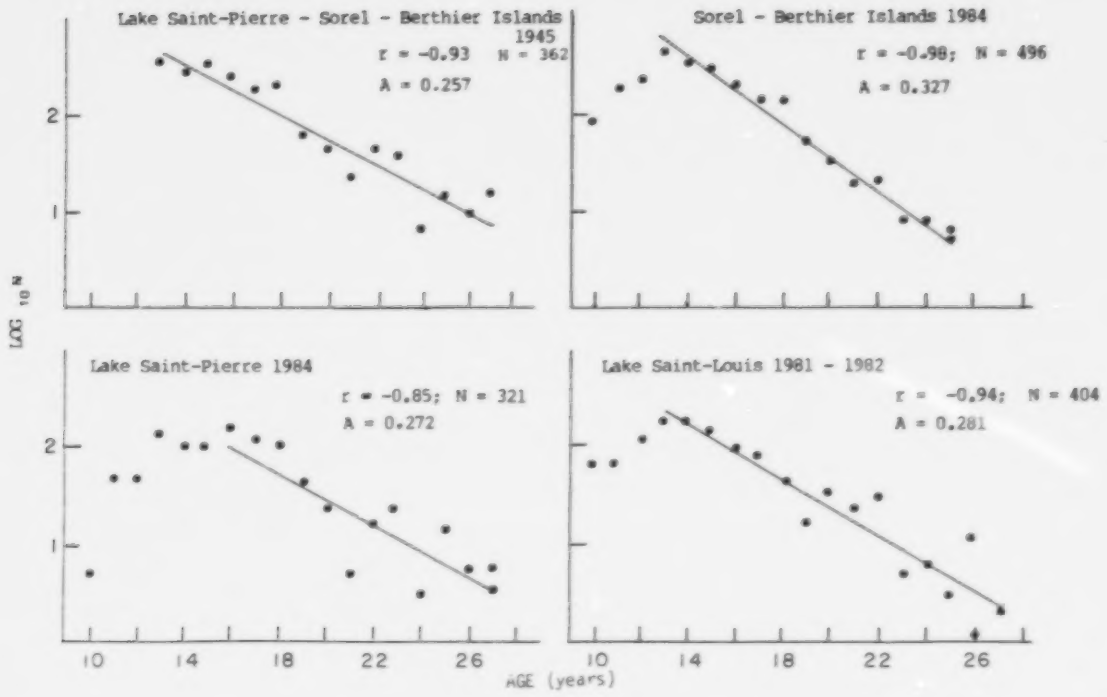
Lake Saint-Pierre - Sorel - Berthier Islands 1945
r = -0.93 N = 362
A = 0.257
Sorel - Berthier Islands 1984
r = -0.98; N = 496
A = 0.327
Lake Saint-Pierre 1984
r = -0.85; N = 321
A = 0.272
Lake Saint-Louis 1981 - 1982
r = -0.94; N = 404
A = 0.281
LOG 10 N
AGE (years)

Fig. 8. Catch curves established from the commercial gillnet catches (19 to 20.3 cm, stretched measure) adjusted for gillnet selectivity.

Table 3. Annual numbers of fish tagged and tag returns by commercial fishermen for sturgeon 800-1,350 mm long. The tag return is given in parenthesis.

	1983 tagging			1984 tagging	
Tagging site	Tagged	Recaptured in 1983	Recaptured in 1984	Tagged	Recaptured in 1984
Longueuil and Laprairie Basin	768	20 (2.6%)	25 (3.3%)	870	17 (2%)
Sorel-Berthier Islands	-	-	-	875	79 (9%)
L'Assomption River	-	-	-	301	7 (2.3%)
Des Prairies River	556	7 (1.3%)	7 (1.3%)	240	3 (1.3%)

catch is not represented and the catch of the sport fishery is under-represented. The latter probably applies to the commercial fishery also, but to a lesser extent. Finally, tag losses, natural mortality and emigration cannot be evaluated. We estimate that exploitation rates (u) probably vary between 10 and 20%.

Total mortality is 4 to 5% higher in the Sorel-Berthier Islands sector than elsewhere in the study area. It is also 6 to 7% higher now than it was 40 years ago in the same area. Fishing pressure for sturgeon is higher in the Sorel-Berthier Islands sector than in Lake Saint-Pierre (Roy 1984). Moreover, there is no reason to believe that natural mortality would be higher in the Islands sector than in Lake Saint-Louis, which is in an urbanized and industrialized area, or in Lake Saint-Pierre, which is immediately downstream. This would suggest that mortality differences must be attributed to a higher exploitation rate. Therefore, exploitation rates of 15 to 20% in the Islands sector and of 10 to 15% elsewhere are likely.

Assuming that this rate did not fluctuate significantly in the past 15 years, and that this sturgeon fishery is a Ricker (1975) type 2 fishery, in which natural and fishing mortality operate concurrently, estimated values of the instantaneous fishing mortality rate (F) would be between 0.18 and 0.24 for the Islands sector and between 0.12 and 0.19 elsewhere. Accordingly, the instantaneous natural mortality rate (M) would be between 0.12 and 0.2, which corresponds to an annual rate (n) of 11.3% to 18.1%. Published values of M for sturgeon in North American are rare. Miller (1972), using tag return data, reported a Z value of 0.15 and an M value of 0.086 for Sacramento - San Joaquin River white sturgeon (*A. transmontanus*). Dadswell (1979), using adjusted catches for gillnet selectivity reported Z values of 0.12 and 0.15 for an unexploited population of shortnose sturgeon in the St. John River estuary. Priegel and Wirth (1975), using a catch curve from the winter spear fishery on Lake Winnebago, Wisconsin, reported Z values between 0.054 and 0.134 and u values between 0.018 and 0.091, indicating that M is probably less than 0.05.

Compared to published rates, our gross estimation of natural mortality is high. However, since our study area is in a highly industrialized and urbanized zone, we think that it is credible. Acute and subacute effects of pollution on sturgeon are not documented, but Saint-Laurent River fish are more exposed to "natural" mortality factors than other populations in less developed areas. For example, in July 1984, we observed the consequences of an "accidental" outflow of toxic effluents. More than 600 sturgeon carcasses were found along the shore indicating that probably many more perished.

Characterization of the sturgeon fishery by sector

Sorel-Berthier Island and Lake Saint-Pierre - In 1983 and 1984, legal catch estimates were 45 to 50 t, corresponding to a yield of 1.4 to 1.6 kg ha^{-1} (for the total area of the sector). More than half of these fish were caught at a small number of sites in a very localized area around the Sorel-Berthier Islands. The number of licences increased from 23 in 1983 to 42 in 1984. In 1983, the daily gillnet fishing success was estimated at 28 kg 100 m^{-1} (Table 4).

Commercial fishing for sturgeon mainly occcurs between mid-June and the beginning of August (Roy 1984). In 1983, 50% of the fishing effort and 80% of the harvest were realized during this period. A similar pattern is described by Cuerrier (1962), except that in 1945, a little fishing effort was exerted during the winter.

From 1945 to the present time, the contribution of small fish to the harvest increased for the Sorel-Berthier Islands sector and decreased for Lake Saint-Pierre. The contribution of very large sturgeon decreased substantially in both sectors. The changes observed in the Sorel-Berthier Islands sector can be associated with an increase in total mortality from 25.7% to 32.7%. It is important to note that this increase was related to events which operated before the sampling period. It does not account for the effects of factors which are contemporary with our study such as the recent significant increase of commercial fishing licenses.

Table 4. Synthesis of information available on lake sturgeon exploitation in the study area. For the lower sectors, single data represent both sectors, paired data represent individual values for Sorel-Berthier Islands and Lake Saint-Pierre.

	Sorel-Berthier Islands Lake Saint-Pierre			Laprairie Basin		Lake Saint-Louis*			Lake Saint-Francois*			
	1945	1983	1984	1983	1984	1982	1983	1984	1947	1964-70	1983	1984
Annual harvest (t)	>19.2	49.1	>43.6	9.3	3.8	>13.5	40	43	-	>3.5	1.2	0.9
Yield (kg ha^{-1})	>0.6	1.6	>1.4	3.4	1.4	>0.9	2.6	2.8	-	>0.2	0.06	0.05
Fishing success (kg 100 m^{-1} days)		28			17							
No. of licenses	-	23	42	3	2	10	10	9	-	-	-	4
<5.4 kg/>5.4 kg	0.95	-	1.81	0.27	0.16	-	0.70	0.54	4.78	-	6	6
			0.46									
>17.7 kg/<17.7 kg	0.05		0.009	0.085	0.189	-	0.026	0.036	0.003	-	0.17	0.09
			0.008									
Mean weight (kg)	7.3	5.1	5.3	8	9	7	7	7.7	4.5	-	0.7	0.4
			6.8									
Annual mortality (%) (age range)	25.7 (13-27)	-	32.7 (13-25)	-	-	28.1 (13-27)	-	-	22.7 (12-22)	25.4 (12-22)	10.8	18.7
			27.2 (16-27)								-	-

*For Lake Saint-Francois, historical data are from Cuerrier and Roussow (1951) and Jolliff and Eckert (1971); they include sturgeon of illegal size and were not adjusted for gillnet selectivity for the estimation of Z. For Lake Saint-Louis, the winter catch was not estimated.

Saint-Laurent River between Sorel-Berthier Islands and Laprairie Basin - Legal fishing in this sector is limited to two small zones. Gross estimations of the 1983 and 1984 catch are 2.9 and 2.8 t (0.23 and 0.22 kg ha^{-1}).

Laprairie Basin - From 1983 to 1984, following the elimination of one fishing license, harvest decreased from 9.3 to 3.8 t, or from 3.4 to 1.4 kg ha^{-1}. The 1984 daily gillnet fishing success was estimated at 17 kg 100 m^{-1} which is lower than in the downstream sectors. Compared to the latter sectors, the contribution of small fish and very large fish were respectively, lower and higher. This is also reflected by a higher mean weight varying between 8 and 9 kg (Table 4).

Fishing mainly occurs during summer but persists until the end of November. Two fishing sites were identified in the Laprairie Basin; again, they represent a small part of the study area. As revealed by the large number of recaptures of fish tagged elsewhere (Table 2), the catch here depends mainly on fish in transit.

Lake Saint-Louis - More than 40 t were harvested for an average yield of 2.6 kg ha^{-1} in 1983 and 1984. The catch from the longline winter fishery was not estimated. During the study period, the number of licences issued decreased from 10 to 9 without a real modification in fishing pressure. Daily gillnet fishing success in 1984 was approximately 37 kg 100 m^{-1}, the highest observed in the study area. Peak harvest periods occur in June-July and September-October, before and after the growing season of drifting filamentous algae, which interferes with gillnet efficiency.

The contribution of small sturgeon is lower than in the downstream sectors and higher than in Laprairie Basin. The situation is reversed when very large sturgeon and mean weight are compared. The total mortality estimate is somewhat higher than it is in Lake Saint-Pierre and lower than in the Sorel-Berthier Islands sector.

Lake Saint-Francois - Cuerrier and Roussow (1951) and Jolliff and Eckert (1971) concluded that the Lake Saint-François sturgeon population was depleted. From the 1923-1933 period to 1984, the harvest of Québec fishermen declined from at least 6.3 t (0.3 kg ha^{-1}) to about 1 t (0.05 kg ha^{-1}). The latter estimations do not include catches by residents of the Saint-Regis International Indian Reserve. Commercial fishing is not allowed in the Ontario and New York waters of Lake Saint-François. In 1984, daily fishing success was 4 kg 100 m^{-1}, which is very low.

The size structure of the harvest is significantly different from what it was in 1947. At that time, the contribution of large sturgeon was very low, indicating low abundance of spawners. This situation probably led to a low occurrence of small sturgeon and a very high occurrence of large sturgeon in the 1983 and 1984 catches. This evolution, when related to low fishing success and low yields, confirms the recruitment problems already diagnosed by Jolliff and Eckert (1971) for the New York waters of Lake Saint-François.

Detrimental effects of the gradual isolation of this population by power dam construction upstream and downstream, along with the associated loss of spawning grounds, have been amplified by the presence of relatively intensive exploitation, as suggested by the estimated mortality rates (not adjusted for selectivity) of Jolliff and Eckert (1971) for the 1947 and 1969-1970 samples (Table 4). For a slow growing, late maturing species, an annual mortality rate of 25% cannot be considered low.

Effects of hypothetical changes in size limits on yield per recruit

Table 5 represents the estimated effects of hypothetical changes in size limits on yield per recruit using the Ricker (1975) equilibrium yield approach. The initial biomass of recruits is 1,000 kg of sturgeon at age 10.

The Lake Saint-Louis and Sorel-Berthier Islands gillnet fisheries (19 to 20.3 cm mesh size) were modeled separately. Equation 1 was used to describe growth in length in the two fisheries but different weight-length relations (equations 2 and 3) were considered. The same instantaneous

Table 5. Effects of hypothetical changes of commercial fishing regulations on total biomass of sturgeon of catchable size ($B_{>10}$); on biomass of sturgeon over 20 years old ($B_{>20}$); and on commercial yield (Y) assuming 1,000 kg of recruits at age 10.

	Lake Saint-Louis			Sorel-Berthier Islands		
	$B_{>10}$	$B_{>20}$	Y	$B_{>10}$	$B_{>20}$	Y
800 mm min. size	6,540	586	924	5,254	282	924
800 mm min. and 1,200 mm max. size	6,828	731	875	5,408	440	902
800 mm min. and 1,300 mm max. size	6,576	623	913	5,271	303	919
1,200 mm min. size	14,633	4,779	406	13,388	3,986	401
900 mm min. size 1,300 mm max. size	8,076	863	860	7,043	472	862
1,000 mm min. size 1,400 mm max. size	10,479	1,472	745	9,415	942	734

natural mortality rate (M = 0.15) was applied to the two fisheries, but a difference of 0.05 in fishing mortality rates was incorporated into the models. Six different size limits were evaluated:

1. 800 m minimum length limit: sturgeon enter the fishery at 10 years old; initial F is 0.05 in Lake Saint-Louis and 0.1 in Sorel-Berthier Islands sector; it increases by 0.05 each year to a respective maximum of 0.2 and 0.25 at age 14; these rates are applied during the next 15 years and decrease by 0.05 at age 29, 33 and 37. Exploitation ceases at age 40. This scenario probably represents the actual conditions.
2. 800 mm minimum and 1,200 mm maximum length limit: same as above except that fishing ceases at age 23.
3. 800 mm minimum and 1,300 mm maximum length: same as above except that fishing ceases at age 28.
4. 1,200 mm minimum length limit: the sturgeon enter the fishery at age 23 and are immediately affected by F values of 0.2 and 0.25, respectively; F decreases gradually at age 29 as in the first case.
5. 900 mm minimum and 1,300 mm maximum length limit: the fish enter the fishery at age 14 and are immediately submitted to the full force of fishing mortality (0.2 and 0.25); fishing ceases at age 28.
6. 1,000 mm minimum and 1,400 mm maximum length limit: sturgeon enter the fishery at age 16 and are immediately submitted to the full force of fishing mortality (0.2 and 0.25) but F decreases by 0.05 at ages 29 and 33; the fish cease to be vulnerable to the fishery at age 34.

Three parameters are considered: $B_{>10}$, which represents the total weight of catchable fish (over 10 years old); $B_{>20}$, which represents total weight of fish over 20 years old and can be considered an index of the biomass of spawners; and Y, yield, or the total weight of fish harvested.

It is important to note that results obtained by these simulations only have a comparative value and that they cannot be extended to other fishing gears. Calculations indicate that, for both sectors, the regulation which offers the highest yield is the 800 mm minimum size limit or, in fact, the present regulation. Three of the regulations implying minimum and maximum length limits (800-1,200 mm, 800-1,300 mm and 900-1,300 mm) would cause only a small reduction in yield (5.3 to 6.9%), but would ensure better protection of potential spawners (increase of 6.3 to 47% on $B_{>20}$).

The 1,200 mm minimum size limit would have a radical effect on each fishery, since it would reduce yield to less than 45% of the present value. Inversely, this scenario ensures the protection of a very large biomass of

potential spawners, which represents one-third of the catchable biomass and 9 to 14 times the biomass of potential spawners protected by the existing regulation.

For each scenario, yield per recruit is approximately equivalent in both sectors. This observation is interesting, since difference in growth rate is not the main cause of this situation. In terms of instantaneous rate of growth (G), the difference is less than 0.01. In fact, a lower rate of fishing mortality allows a larger catchable biomass, which finally produces an equivalent yield. In other words, for the same total harvest, fish are less numerous but larger in Lake Saint-Louis than in the Sorel-Berthier sector.

A lower rate of fishing mortality also ensures greater protection to the potential spawning stock in each scenario. For the 800 mm minimum size limit, the biomass of spawners protected in the Sorel-Berthier Islands sector is less than 50% of the equivalent figure in Lake Saint-Louis. Differences of the same order are observed for the 800-1,300 mm, 900-1,300 mm and 800-1,200 mm minimum and maximum length limits.

DISCUSSION

With the exception of the Lake Saint-François fishery, which is depleted, mean annual yield was approximately 1.3 kg ha^{-1} in recent years. This value is extremely high. Priegel and Wirth (1975) reported a mean annual yield of 0.21 kg ha^{-1} for the Lake Winnebago sport fishery, and Sunde (1961) suggests an annual sustainable yield of 0.11 to 0.19 kg ha^{-1} for Manitoba rivers. In the Saint-Laurent River, the lake sturgeon fishery has been in operation for a long time and yields have probably always been comparatively high.

We think that three major factors account for the high yields observed in the study area. Firstly, the lake sturgeon seems to profit by the moderate productivity of the Saint-Laurent River waters. Secondly, intensive commercial fishing is restricted to specified zones. Fishing pressure is low in Lake des Deux Montagnes, in the Saint-Laurent River between the Laprairie Basin and the Sorel-Berthier Islands and in the large tributaries where sturgeon occur. These "sanctuaries", which act as reservoirs for other sectors, are undoubtedly important. Thirdly, the gill nets used by the commercial fishermen are relatively selective. In fact, the gillnet fishery is presently operated under a combined minimum-maximum length limit. When the exploitation rate is not too high, this allows some protection to the spawning stock, which is composed of long-lived and highly fecund multiple spawners. However, longlines, which are used less extensively than gill nets, are less selective and can catch very large sturgeon (up to 90 kg in 1983). An intense fishing effort with this gear would have detrimental effects on the sturgeon population.

Simulations indicate that, using the same mesh size, different minimum-maximum length limits (800-1,200; 800-1,300; and 900-1,300 mm) would ensure a greater protection to the spawning stock than the present 800 mm minimum size limit, without an excessive decrease in yield. A relatively high minimum length limit (1,200 mm), which is generally used or proposed for lake sturgeon fishery management, would reduce yield drastically. These conclusions can probably be applied to all sturgeon populations affected by a relatively high natural mortality, as in the present study, or more precisely by a negative balance between G and M occurring at a low age. Therefore, they can probably be applied to exploited populations in northern Québec and Ontario. Generally, in these slow growing populations, natural mortality is low, but may rapidly exceed growth.

In our study area, sturgeon age 13 to 28 also sustained a high fishing mortality. Analysis of harvest characteristics, comparisons with historical data and simulations indicate that fishing pressure is probably too high in the Sorel-Berthier Islands sector. A lower exploitation rate would produce an equivalent yield and would ensure better protection to the spawning stock.

From Lake Saint-Louis to Lake Saint-Pierre, lake sturgeon probably form a

single population. However, homogeneity is not complete, since differences in growth in weight and in harvest structure were observed between the upper and lower part of the study area. This question of stock homogeneity is important, since it involves the relative interdependence of fisheries which are located at both ends of our study area (excepting Lake Saint-François). Consistency in lake sturgeon management, in terms of habitat protection, rehabilitation, fishery regulation and monitoring, is essential.

In the study area, lake sturgeon occur in large numbers in small localized sites. Also, spawning grounds seem to be quite scarce. These conditions increase their vulnerability to fishing gear and to any intervention on these local habitats (filling, dredging, toxic outflows, etc.).

As a result of the information gathered during the past four years of this long-term study, several positive measures have been, or will be, undertaken. A dredging project near the Longueuil tagging site was modified. A filling project on a spawning ground was stopped and this spawning ground enlarged. Stricter contaminant criteria will be considered for a pulp and paper effluent treatment plant discharging 2 km upstream of a spawning ground. New operating criteria were tested to ensure access to a spawning ground used before the construction of a dam in 1960 in the upper part of Lake Saint-Louis. The absolute necessity of maintaining free passage between Lake Saint-Louis and the Laprairie Basin was demonstrated; this point is very important, since a power dam project in the Lachine Rapids located between these two lakes is under study. Sport and commercial fishing seasons were shortened by 30 and 45 days, respectively, to ensure better protection of the spawning stock.

Future monitoring of this sturgeon fishery includes three elements: accurate catch and effort statistics; a tag return study; and periodic sampling of the harvest once every three years. Research must also be continued in at least two areas: the sexual maturation cycle and identification of spawning grounds. Rehabilitation of the spawning stocks in some tributaries must also be considered.

ACKNOWLEDGEMENTS

This study was initiated by G. Massé. It was supported by B. Vincent, P. Fournier and J.-G. Forget, Direction régionale de Montréal of Ministère du Loisir, de la Chasse et de la Pêche, C. Pomerleau, Direction de la Faune Aquatique and M. Lafleur, Direction Régionale de Trois-Rivières. We are indebted to colleagues who were involved in the field and laboratory work: M. Beaudoin, J. Brisebois, M. Bureau, Y. Chagnon, S. Desjardins, B. Dumas, N. Fournier, J. Leclerc, J.-R. Mongeau, R. Parent, G. Roy, Y. Sarrazin, C. Simard, L. Bazin, D. Bourbeau, M. Corriveau, J. Scrosati, P. Leclerc, J. Provost, M. Trioreau, M. Henry, S. Desloges, M. Hardy, G. Guay, R. Verdon, P. Laramée, J. Dumont, F. Bousquet and L. Richer. Mr. J.-P. Cuerrier readily put at our disposal unpublished data and much useful information on the 1945-1950 period. Many commercial fishermen facilitated our field and sampling work. Figures were drawn by P.-A. Roy and Ginette Morel typed the manuscript. C. Brousseau, A. Sandilands, C. Jessop, T. Mosindy and N. Wilson reviewed the preliminary version of the manuscript.

REFERENCES

CUCIN, D., and H. A. REGIER. 1966. Dynamics and exploitation of lake whitefish in southern Georgian Bay. J. Fish. Res. Board Can. 23: 221-274.

CUERRIER, J.-P. 1945. Les stades de maturité chez l'esturgeon du lac Saint-Pierre. Québec, Ministère de la Chasse et de la Pêche, Office de Biologie, Rapp. Ms. 14 p.

CUERRIER, J.-P. 1951. The use of pectoral fin rays for determining age of sturgeon and other species of fish. Can. Fish Cult. 11:10-18.

CUERRIER, J.-P. 1962. Inventaire biologique des poissons et des pêcheries

de la région du lac Saint-Pierre. Nat. Can. 89:193-214.

CUERRIER, J.-P. 1966. Observations sur l'esturgeon de lac *Acipenser fulvescens* Raf. dans la région du lac Saint-Pierre au cours de la période du frai. Nat. Can. 93:279-334.

CUERRIER, J.-P., and G. ROUSSOW. 1951. Age and growth of lake sturgeon from Lake St-Francis, St-Lawrence River. Can. Fish Cult. 10:17-29.

DADSWELL, M.J. 1979. Biology and population characteristics of the shortnose sturgeon, *Acipenser brevirostrum* Le Sueur 1818 (Osteichthyes: *Acipenseridae*) in the Saint John River estuary, New Brunswick, Canada. Can. J. Zool. 57:2186-2210.

DUMONT, P., G. DESJARDINS, R. FORTIN, N. FOURNIER, et M. BERNARD. L'Esturgeon jaune, *Acipenser fulvescens*: biologie et exploitation dans les eaux du fleuve Saint-Laurent et de l'archipel de Montréal. Québec, Ministère du Loisir, de la Chasse et de la Pêche, Service de l'aménagement et de l'exploitation de la faune, Rapp. Tech. 06-41. (en préparation)

HAMLEY, J. M. 1975. Review of gillnet selectivity. J. Fish. Res. Board Can. 32:1943-1969.

JOLLIFF, T. M., and T. H. ECKERT. 1971. Evaluation of present and potential sturgeon fisheries of the St. Lawrence River and adjacent waters. N.Y.S. Dep. Environ. Conserv., Cape Vincent Fish. Sta. 113 p.

KEIGHAN, E. 1977. Caractérisation du niveau d'enrichissement et de la toxicité des eaux du bassin du fleuve Saint-Laurent. Pêches et Environ. Canada. Préparé pour le Comité d'Etude sur le Fleuve Saint-Laurent, Rapp. Tech. 6. 153 p.

LECLERC, J. 1984. Marquage et repérage radiotélemétriques de 11 espèces de poisson du territoire central du projet archipel entre Octobre 1982 et Août 1983. Québec, Ministère du Loisir, de la Chasse et de la Pêche, Service Archipel, Rapp. Tech. 5. 164 p.

MAGNIN, E. 1962. Recherches sur la systématique et la biologie des Acipenséridés *Acipenser sturio* L. *Acipenser oxyrhyncus* Mitchill et *Acipenser fulvescens* Raf. Paris, Annales de la station centrale d'Hydrobiologie appliquée 9. 242 p.

MAGNIN, E. 1977. Croissance, régime alimentaire et fécondité des esturgeons *Acipenser fulvescens* Rafinesque du bassin hydrographique de la Grande Rivière (Québec). Nat. Can. 104: 419-427.

MAGNIN, E., et G. Beaulieu. 1960. Déplacements des esturgeons *Acipenser fulvescens* et *A. oxyrhyncus* du fleuve Saint-Laurent d'après les données de marquage. Nat. Can. 87: 237-252.

MILLER, L. W. 1972. White sturgeon population characteristics in the Sacramento San Joaquin estuary as measured by tagging. Calif. Fish Game 58:94-101.

MONGEAU, J.-R., J. LECLERC, et J. BRISEBOIS. 1982. La dynamique de la reconstitution des populations de l'Esturgeon jaune, *Acipenser fulvescens* du lac des Deux Montagnes, province de Québec, de 1964 à 1979. Québec, Ministère du Loisir, de la Chasse et de la Pêche, Service de l'aménagement et de l'exploitation de la faune, Rapp. Tech. 06-33. 191 p.

PRIEGEL, G. R., and T. L. WIRTH. 1971. The lake sturgeon: its life history, ecology and management. Wis. Dep. Nat. Resour. Publ. 240-70. 20 p.

PRIEGEL, G. R., and T. L. WIRTH. 1975. Lake sturgeon harvest, growth and recruitment in Lake Winnebago, Wisconsin. Wis. Dep. Nat. Resour. Tech. Bull. 83. 25 p.

PROBST, R. T., and E. L. COOPER. 1954. Age, growth and production of the lake sturgeon (*Acipenser fulvescens*) in the Lake Winnebago region, Wisconsin. Trans. Am. Fish. Soc. 84: 207-226.

PROVOST, J., R. FORTIN, G. PATENAUDE, J. PICOTTE, et P. P. HAZEL. 1982. Localisation des frayères et utilisa-

tion des hauts-fonds par la faune ichtyenne, site Rivière-des-Prairies. Projet de remplacement de l'évacuateur de crue et d'arasement d'un haut-fond. Univ. du Québec à Montréal, Département des Sciences biologiques. Préparé pour la vice-présidence Environnement, Hydro-Québec. 90 p. + 7 annexes.

RICKER, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191. 382 p.

ROUSSOW, G. 1955. Les esturgeons du fleuve Saint-Laurent en comparaison avec les autres espèces d'Acipenséridés. Québec, Ministère de la Chasse et Pêcheries, Office de Biologie. 123 p.

ROY, C. 1984. Répartition et sélectivité des filets maillants, des lignes dormantes et des seines à la pêche commerciale, dans la région du lac Saint-Pierre, 1983. G.D.G. Environnement Mauricie Inc., Trois-Rivières, Rapp. non publié. 37 p.

SUNDE, L. S. 1961. Growth and reproduction of the lake sturgeon *Acipenser fulvescens* Rafinesque of the Nelson River in Manitoba. M.Sc. thesis, Univ. British Columbia. 93 p.

WIRTH, T., and C. CLINE. 1955. The harvest of lake sturgeon by spearers in Lake Winnebago and connecting waters, Wisconsin. Wis. Conserv. Dep., Mimeo. 11 p.

AGE DETERMINATION OF LAKE STURGEON (*ACIPENSER FULVESCENS*) BY USE OF THE MARGINAL PECTORAL FIN RAY

N. C. Wilson
Ontario Ministry of Natural Resources, P.O. Box 3000, Cochrane, Ontario P0L 1C0

Recommendations have been made to sever the marginal pectoral fin ray of the lake sturgeon (*Acipenser fulvescens*) at 3-5 mm from the point of articulation with the body wall to minimize blood loss and maximize the reliability of age data. The thickness of the fin ray cross-section which was most useful for determining age was 250 μ to 400 μ. Various problems associated with age determination are discussed.

INTRODUCTION

Knowledge of the age structure of a fish population is necessary for management purposes. Age is required to determine longevity, growth rates, mortality rates and maturation of fish species within different aquatic environments. It is the intent of this paper to describe an anatomical method of determining age for the lake sturgeon (*Acipenser fulvescens*).

It is important to select the calcified tissue that will yield the most accurate age and yet be practical to collect. If the sturgeon sampled are to be released alive, aging tissues are limited to external body parts. Unlike most fish species, sturgeon have no scales with which to determine age, thus limiting the external aging structures to the scutes (hard plates) and the fin rays. However, the scutes undergo degeneration and disappear almost completely as the adult stage is reached (Cuerrier 1951). Roussow (1957) found that not all fins of the sturgeon were suitable for age determination. Only the first ray of the pectoral fins is ossified; the remainder are cartilaginous (Scott and Crossman 1973). The use of the marginal (first) pectoral fin ray of lake sturgeon has been generally accepted and widely used, even when other bony structures were available for sampling from sacrificed sturgeon. A summary of material on sturgeon aging is presented by Cuerrier (1951). More recent literature on the suitability of the marginal pectoral fin ray for determining age has been presented by Probst and Cooper (1954), Roussow (1957), Young and Love (1970), Priegel and Wirth (1971), Huff (1975) and Threader (1981).

Fish retained by anglers, commercial fishermen and government agencies can be used to provide other calcified aging structures. Resorption of the cleithra in older sturgeon was noted by Cuerrier (1951), thus limiting their usefulness as an aging structure. Other investigators (Harkness 1923; Schneberger and Woodbury 1944) have used otoliths successfully to determine age, although preparation time is somewhat longer than that of the marginal fin ray. Otoliths can be used to supplement the age information obtained from the marginal pectoral fin rays. Huff (1975) aged both the marginal pectoral fin rays and operculi from 26 specimens of the Gulf of Mexico sturgeon (*A. oxyrhynchus desotoi*) and found that the ages from the fin ray sections were 2 to 7 years older than those determined from the operculi. He felt that age determinations from the operculi were unreliable because the circuli became obscured in older fish.

Most recent lake sturgeon studies involve the release of live sturgeon which permits the use of only one viable aging structure - the marginal pectoral fin ray. This paper will deal with the methods involved in the removal, sectioning and aging of the marginal pectoral fin ray, based on experience obtained from aging approximately 300 lake sturgeon from the Abitibi and Mattagami rivers in northern Ontario. The fin rays were taken from sturgeon caught during large river surveys (1984 and

1985) conducted by the Ontario Ministry of Natural Resources (OMNR). The resulting age data have been analysed by Payne (1987).

REMOVAL OF FIN RAYS

There are two areas where the marginal pectoral fin ray may be removed: either at the point of articulation with the body wall, or slightly farther up the marginal ray. The first area causes more blood loss and stress to the sturgeon. Threader (1981) studied the variations in age determination as the distance from the body wall articulation point increased. He noted that considerable errors in aging could occur if the distance at which the ray was removed from the body wall was more than 1 cm. He found that in a sample of 20 fish, the mean age declined 11.7, 27.1, 31.8 and 41.1% for fish aged from fin rays removed at 1, 2, 3 and 4 cm, respectively, from the body wall compared to those aged at the point of articulation. Threader (1981) recommended that aging be determined from a pectoral fin ray section taken as close to the body wall as reasonably possible, thus creating some error in age determination, but reducing stress and blood loss to the sturgeon. Roussow (1957) considered that a possible error of a year is of no great importance in sturgeon aged at more than 10 years old. The fin ray should be severed 3-5 mm from the body wall (Fig. 1). This permits sections of reliable age to be obtained while reducing blood loss from the sturgeon.

Either the left or right marginal pectoral fin ray may be removed, but for consistency it is recommended that the fin ray be taken from the same side of each fish sampled. The ray is removed by slitting the integument between the first and second rays of the pectoral fin with a knife and then using bone cutters to sever the marginal fin ray 3-5 mm from the body wall. The ray can be stored in a lined scale envelope to dry, or set aside (suitably labelled) to air dry before placing it in an envelope to prevent sticking. The rays must be stored in a warm dry place and thoroughly dried for three to four weeks before sectioning and aging to reliably differentiate between summer and winter growth.

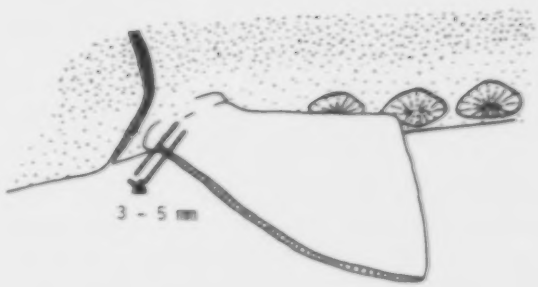

Fig. 1. The marginal pectoral fin ray showing the distance it should be severed from the point of articulation with the body wall to minimize blood loss and maximize reliability of age data.

SECTIONING AND PREPARING FIN RAYS

An 'Isomet 11-1180 Low Speed Saw' with a 10 cm diamond wafering blade with a tap water blade bath was used to section sturgeon fin rays. The ray was solidly clamped in the chuck to prevent blade damage and adjusted so that the section cut was perpendicular to the ray itself (transverse or cross-section). Faster rotation speeds and heavier weights tended to damage the section surface. Adequate sections were obtained using a 275 g weight on the weight shaft of the support arm and a speed setting of 5-7 (150-210 RPM). Saw cuts could be seen but these did not interfere with the reading of the annuli.

The first cut was made as close to the end of articulation as possible to obtain a full section with the next cut. The most readable sections were between 250 µ and 400 µ thick. Sections thinner than 250 µ showed little differentiation between summer and winter growth. Sections thicker than 400 µ prevented light transmission and obscured some annuli. Some annuli became more apparent by varying the thickness of the sections cut. Generally, the desired thickness was achieved by turning 25

notches on the micrometer, but this will vary with the machine so that a hand micrometer was essential in determining what thickness was achieved with a particular calibration. Adjustments were made accordingly.

Sections were then washed in tap water followed by 70% alcohol. Probst and Cooper (1954) found that glycerine was not as satisfactory as alcohol, as it penetrated slowly and had to be completely removed through alcohol baths in order to prevent permanent clearing. They also found that alcohol produced a higher degree of differentiation between translucent and opaque zones. A compound microscope (40x magnification) was useful when set up beside the saw for examining the sections as they were cut and washed. Age may be determined in younger sturgeon (under twenty years) with one or two sections. With older fish, five sections usually produced a few 'readable' sections. Sections were aged after cutting and then set aside on a microscope slide to dry overnight prior to storage. Most mounting mediums should not be used as they have a clearing agent in them which, in time, will eliminate the differentiation in growth patterns. For this reason, I stored the sections dry, in their original scale envelopes, so that further examination, if warranted, is possible. Due to the thickness of the sections, curling when drying was minimal.

AGING AND ASSOCIATED PROBLEMS

Upon initial examination of sturgeon fin ray sections, zones of opaque and translucent qualities, corresponding to summer and winter growth periods respectively, were evident. Under transmitted light, these zones will appear dark for summer growth and light for winter growth. By counting the light bands present, the age can be determined (Cuerrier 1951; Probst and Cooper 1954; Roussow 1957). However, the aging of marginal fin ray sections involves some interpretation.

The irregular cross-sectioned shape of the marginal ray suggests that certain areas of the section are more conducive for determining age. The area that has the greatest distance from the centre of ossification to the most recent growth zone is generally the clearest area in which to view the annuli. On the marginal pectoral fin ray, this was the posterio-lateral regions of the section (Fig. 2).

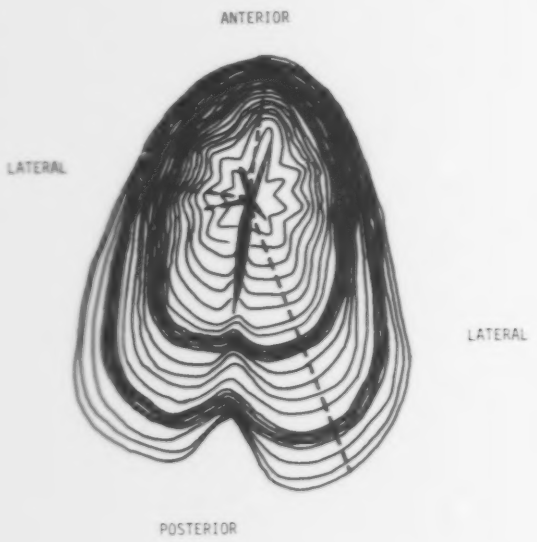

Fig. 2. Cross-section of a marginal pectoral fin ray section. The posterio-lateral region provides the best age interpretation as the annuli are spread over a greater distance and are more readily distinguishable.

The marginal ray of the pectoral fin is well developed by the first winter, having been formed as early as the 6th or 7th day after hatching (Roussow 1957). Cuerrier (1951) interpreted the first winter ring as the first translucent zone following the centre of ossification. Roussow (1957) called this first seasonal zone the 'central star', owing to its unique shape (Fig. 3a). Sections taken farther away from the articulation point may not show this first seasonal zone. If the section is taken close to the articulation point, the existence of the first annulus may still be determined. Generally, the area of calcification within the second annulus is much greater than that which would have been found within the first annulus. This area, however, will decrease as you get farther away from the point of articulation. The exis-

Fig. 3. Partial sections of the marginal pectoral fin ray of lake sturgeon (40x) showing:

a) The 'central star' (arrow) and secondary ray imbedded in marginal ray (broken outline).
b) Double and triple annuli.
c) False annuli.
d) Configuration of a previously fractured ray.

tence of a previous seasonal zone may be indicated by the presence of spots with a translucent appearance. Under transmitted light, these appear as light patches where the points of the 'central star' used to be.

There are a variety of factors that influence the growth rate of sturgeon. Priegel and Wirth (1971) noted that variation in the rate of growth between sturgeon differs within the same river or between sturgeon from different waters, and can be influenced by water temperature and amount of available food. Migration, spawning periods and injury or disease also affect the rate of growth (Roussow 1957). For these reasons, uniform banding is not always present.

As sturgeon are relatively long-lived fish, many annuli are present on sections from 3 to 7 mm in diameter. These annuli are very close together and one summer of slow growth might clump two annuli together. Such a distinction may or may not be discernable under magnification. After examining fin ray sections of older fish, it became apparent that banding or clumping (several years of closely spaced annuli) was a regular occurrence. Roussow (1957) found that after 10 or more years of wide spacing, the annuli abruptly become narrower and remained so for several years. This first belt is followed by several wide annuli and then a second narrow belt - a pattern that is repeated several times in older fish. He suggested that at least part of each band of narrow annuli should be assigned to the period immediately before spawning, and that rapid growth is resumed either immediately after spawning (same year) in order to produce a broad annulus for that season, or possibly a year after spawning to incorporate a recuperation period. From the fin ray sections, Roussow (1957) was able not only to determine age and periods of unfavourable growth, but also the age at first spawning, the sex (due to different maturation rates between the sexes) and the intervals between the spawning periods.

In the present study, the first band of narrow growth was easily determined, but delineation of the remaining bands was extremely difficult. Several narrow annuli may appear as one very thick annulus during the period of slower growth before spawning. By varying the thickness of fin ray sections these annuli might be detected, but generally it was impossible to determine precisely how many annuli actually formed the band. It was therefore necessary to indicate that the assigned age was actually a minimum age, due to the presence of one or more bands of clumped annuli of which the number of annuli present could not be determined.

Huff (1975) found that the primary causes of questionable ages in the Gulf of Mexico sturgeon were the presence of double annuli, false or incomplete annuli and difficulty in determining the first annulus. Multiple annuli (annuli composed of two or more closely spaced zones formed within one winter season) were also observed in some lake sturgeon in the present study (Fig. 3b). It was necessary to follow the annulus around the section to determine if it was actually one annulus or two separate annuli. False annuli had a tendency to fade out and were not as continuous as true annuli (Fig. 3c). It is important, therefore, to cut sections of varying thickness, especially in older fish, where many annuli are present. It may be necessary to determine age using more than one section.

Roussow (1957) suggested that the two rays closest to the marginal ray may be used as a control in reading the first ray if one or two years are added to the interpreted age. This may not be feasible for fish where the annuli are extremely close together and sometimes indistinguishable. Occasionally, one or both of the secondary rays was imbedded within the marginal ray (Fig. 3a). It then became necessary to count the annuli down to the secondary ray and then continue to count the annuli which remained past the secondary ray. Probst and Cooper (1954) considered the shape and diameter measurements of sections of the marginal ray too variable to attempt back calculations (the relationship between fish length and fin ray measurement), especially with the incorporation of the next posterior ray.

Sturgeon often fracture fin rays trying to reach upstream spawning beds during migration periods. These fin

rays will regenerate, but the formation of seasonal zones is disturbed. A cross-section taken through a previously fractured ray will show an irregular growth pattern (Fig. 3d). Although it will be impossible to determine age by counting the seasonal zones at the point of fracture, Roussow (1957) suggested that sections taken from parts proximal to the fracture may permit age determination. Sections taken through parts distal to the fracture do not always give the same results since normal growth has been disturbed.

Generally, sturgeon under 20 years old are the most easily aged. The ages assigned older fish are largely dependent on personal interpretation. In an age comparison of lake sturgeon from the Ottawa River (M. Strickland, OMNR, Parry Sound, Ont. P2A 1S8, pers. comm.), three experienced agers independently assigned ages to 64 sturgeon. The ages ranged from 24 to 58 years. No individual fish was assigned the same age by all three agers. However, at least two of the three agers agreed 17% of the time, were within one year of each other 47% of the time, and within two years 62% of the time. Problems associated with aging marginal fin ray sections of lake sturgeon must be taken into account when interpreting age data.

The lake sturgeon studies mentioned in this paper were undertaken without determining the effects of fin ray removal upon the survival of the fish. Kolhorst (1979) evaluated tag returns of white sturgeon (*Acipenser transmontanus*) to determine the effect of marginal pectoral fin ray removal. He concluded that the removal of this fin ray caused substantial mortality (36%) during the year following release and less mortality thereafter. For this reason, similar follow-up studies are necessary to determine whether the removal of the marginal pectoral fin ray is a significant mortality factor in lake sturgeon.

ACKNOWLEDGEMENTS

I would like to thank Chris Brousseau (OMNR, Northern Region) for his many editoral comments during the preparation of this report.

REFERENCES

CUERRIER, J.-P. 1951. The use of pectoral fin rays for determining age of sturgeon and other species of fish. Can. Fish Cult.11:10-18.

HARKNESS, W. J. K. 1923. The rate of growth and the food of the lake sturgeon (*Acipenser rubicundus* Le Sueur). Univ. Toronto Stud. Biol. Ser. No. 24. Publ. Ont. Fish. Res. Lab. 18: 15-42.

HUFF, J. A. 1975. Life history of Gulf of Mexico sturgeon, *Acipenser oxyrhynchus desotoi*, in Suwannee River, Florida. Fla. Mar. Res. Publ. 16. 31 p.

KOLHORST, D. W. 1979. Effect of first pectoral fin ray removal on survival and estimated harvest rates of white sturgeon in the Sacramento-San Joaquin estuary. Calif. Fish Game 65:173-177.

PAYNE, D. A. 1987. Biology and population dynamics of lake sturgeon (*Acipenser fulvescens*) from the Frederick House, Abitibi and Mattagami rivers, Ontario, p. 10-19. *In* C.H. Olver [ed.] Proceedings of a workshop on the lake sturgeon (*Acipenser fulvescens*). Ont. Fish. Tech. Rep. Ser. No. 23. 99 p.

PRIEGEL, G. R., and T. L. WIRTH. 1971. The lake sturgeon: its life history, ecology and management. Wis. Dep. Nat. Resour. Publ. 240-70. 19 p.

PROBST, R. T., and E. L. COOPER. 1954. Age, growth and production of the lake sturgeon (*Acipenser fulvescens*) in the Lake Winnebago region, Wisconsin. Trans. Am. Fish. Soc. 84: 207-227.

ROUSSOW, G. 1957. Some considerations concerning sturgeon spawning periodicity. J. Fish. Res. Board Can. 14: 553-572.

SCHNEBERGER, E., and L. A. WOODBURY. 1944. The lake sturgeon (*Acipenser fulvescens* Rafinesque), in Lake Winnebago, Wisconsin. Trans. Wis. Acad. Sci. Arts Lett. 36:131-140.

SCOTT, W. B., and E. J. CROSSMAN. 1973. Freshwater fishes of Canada. Fish. Res. Board Can. Bull. 184. 966 p.

THREADER, R. W. 1981. Age, growth and proposed management of the lake sturgeon (*Acipenser fulvescens*) in the Hudson Bay lowland. Ont. Min. Nat. Resour., Moosonee Dist. Ms Rep. 106 p.

YOUNG, J. K., and G. F. LOVE. 1970. The lake sturgeon (*Acipenser fulvescens*) of Lake Nipissing. Ont. Dep. Lands Forests, North Bay Dist. Ms Rep. 24 p.

LAKE STURGEON (*ACIPENSER FULVESCENS*) MANAGEMENT AND CULTURE IN MINNESOTA AND MICHIGAN[1]

E. R. Anderson
Minnesota Department of Natural Resources, Metro Region Headquarters,
Section of Fisheries, St. Paul, MN 55106

A three year study was conducted in the state of Michigan to evaluate the feasibility of culturing lake sturgeon (*Acipenser fulvescens*).

Unique aspects of the study included: (1) Observation of pre- and post-spawning lake sturgeon, and (2) a major effort directed at collecting gametes during the peak of spawning. Eggs were removed by cesarean section and milt by syringe; all fish were released unharmed. Standard fertilization techniques were utilized. Bentonite was used to alleviate clumping of the eggs which were then incubated in standard McDonald jars.

First-feeding fry were fed zooplankton and aquatic annelids. Semi-moist artificial diets were fed to specific lots of sturgeon. Survival with artificial diets was found to be poor compared to natural diets, thus indicating that natural diets should be considered over artificial diets at this time (Anderson 1984[2]).

The Minnesota Department of Natural Resources is currently conducting a five year study to reestablish the lake sturgeon in the St. Louis River, near Duluth, Minnesota. All sturgeon used for this project are procured through artificial propagation. During the fall of 1985, approximately 5,700 13 to 18 cm (5-7") lake sturgeon fingerlings were stocked into the St. Louis River. All of these sturgeon were coded-wire tagged. The reestablishment of the lake sturgeon in the St. Louis River is federally supported by the United States Fish and Wildlife Service, under the Anadromous Fish Conservation Act.

[1]Editor's note: During the formal session Mr. Anderson presented an illustrated slide talk detailing his experience with lake sturgeon spawning and culture operations in Minnesota and Michigan. During an informal evening session, he showed a videotape of lake sturgeon spawning and spawn-taking activities.

[2]Anderson, E. R. 1984. Artificial propagation of lake sturgeon (*Acipenser fulvescens* Rafinesque) under hatchery conditions in Michigan. Mich. Dep. Nat. Resour., Fish. Div., Fish. Res. Rep. 1898. 32 p.

CONSIDERATIONS FOR THE MANAGEMENT OF LAKE STURGEON (*ACIPENSER FULVESCENS*) COMMERCIAL FISHERIES IN ONTARIO

M. L. Hart
Ontario Ministry of Natural Resources, Box 605, Brockville, Ontario K6V 5V8

This paper provides a review of the management of commercial fisheries for lake sturgeon (*Acipenser fulvescens*) in Ontario. Opportunities for innovative management are discussed with consideration allowed for the social and economic aspects of regulatory management and the paucity of information on sturgeon. It is only through the collection of biological data and population assessment that regulatory management can be justified. A proposed amendment to the Ontario Fishery Regulations, if approved, will allow managers to control harvest on an area and stock specific basis. This paper includes the concerns and recommendations of the commercial fishing discussion group during the Lake Sturgeon Management Workshop, February 1986, Timmins, Ontario.

INTRODUCTION

Lake sturgeon (*Acipenser fulvescens*) populations in most Ontario waters have declined rapidly since the turn of the century. Recent interest in sport fishing for sturgeon, demand for sturgeon products and access to new stocks in previously isolated areas have resulted in concern for the future management and perpetuation of lake sturgeon. Overfishing has resulted in the collapse of sturgeon fisheries on many waters where commercial harvest has occurred. Habitat degradation has also contributed to this decline. The construction of dams, shoreline alterations, and the entry of natural and chemical waste products into sturgeon waters have adversely affected spawning habitat and impacted forage availability (Brousseau 1987; Dumont et al. 1987; Mosindy 1987; Payne 1987). Regulations intended to control harvest and manage lake sturgeon have been inadequate. Given the biology of the species and its habitat requirements (Brousseau 1987), prompt and sound management prescriptions must be applied.

All too often, the literature provides documentation of collapsed fisheries as a result of overfishing and habitat destruction (Brousseau 1987; Mosindy 1987). The inadequately regulated commercial harvest of lake sturgeon in Ontario has been a major factor in the decline of the fisheries. Lake sturgeon populations that have been commercially exploited are diminished and population recovery is seldom evident.

Increasing demand for commercial fish to supply market needs and the recent interest in angling for sturgeon is placing additional stress on the remaining sturgeon stocks. Subsistence fishing by native peoples on some waters may result in overfishing. Remedial action in this situation presents a true dilemma.

Studies have shown that maturity, yield, mortality and standing stocks of lake sturgeon are subject to considerable variation between watersheds (Nowak and Jessop 1987; Payne 1987; Sandilands 1987). The biology of the lake sturgeon sturgeon and the stressors initiated as the result of habitat loss, as well as sport and commercial harvest indicate that the lake sturgeon has a low sustainable yield. Nowak and Jessop (1987) found that on the Groundhog River, angler harvest equals or exceeds annual production. They suggested that the fishery is on the threshold of overexploitation; a situation which precludes the opportunity for commercial harvest.

Gear selectivity and the choice of harvest control techniques is complicated by variations in growth rate and maturity between sexes, both within populations and between watersheds. Due to very small sample sizes, biologists

often place low confidence on population estimates, mortality rates and estimates of recruitment. Even without reliable predictions of sustainable yield, the manager still has to assign harvest quotas to commercial fisheries.

Habitat degradation by itself can result in the decline and collapse of a sturgeon population. Log drives and pulp and paper mill operations result in tree bark and wood fibre settling to the river bed and this, in combination with mill effluent, can impact the production of invertebrates, a major food source for sturgeon. Habitat alteration and deterioration of water quality will also impact spawning habitat, and hatching and survival of lake sturgeon. Dam construction in northern rivers may have isolated sturgeon populations, thereby preventing access to spawning habitat and preventing seasonal movements. Payne (1987) suggets that water level fluctuations caused by water control dams during pre/post spawning periods may have resulted in the collapse of stocks in the Mattagami River.

Toxic effluents can have an immediate effect on a sturgeon fishery. Dumont et al. (1987) described the effect of toxic effluents on sturgeon in the St. Lawrence River. Toxic effluents can have a less immediate effect by reducing forage availability. Contaminant levels in sturgeon flesh have resulted in the closure of commercial fisheries for sturgeon in the St. Lawrence River in Ontario and portions of the Ottawa River.

Commercial fishing and its regulation cannot be considered by itself. Alone, unregulated commercial harvest has resulted in the collapse of sturgeon populations. In combination with sport fisheries, inadequate regulations and habitat degradation, the collapse of sturgeon stocks and their fisheries appears inevitable.

LAKE STURGEON COMMERCIAL FISHERY REGULATIONS IN ONTARIO

The current Ontario Fishery Regulations do not allow the fisheries manager an area specific capability needed to manage the lake sturgeon fishery. The present regulations provide minimum size limits, describe the type and amount of commercial gear that can be used, and state seasons when lake sturgeon may be commercially harvested.

The results of recent sturgeon studies show that age of maturity varies between watersheds and even within watersheds. Length-at-age and weight-at-age for sturgeon considered to be of spawning age also differ between water bodies. In the Kenogami River, males are mature at age 21 to 25 and females reach spawning age at age 25 to 31 (Sandilands 1987). For this age group, the length-at-age range varies from 72 to 98 cm. Nowak and Jessop (1987) reported that males are mature by age 19, females by age 22 and the length-at-age range is 98 cm to 105 cm. In Lake of the Woods, males first mature at age 20 and females at age 25 (Mosindy 1987). The length-at-age range is 117 cm to 124 cm. This disparity in age and length at maturity, both between males and females and between different stocks, suggests that the manager must adjust regulations to meet the needs of individual sturgeon fisheries. Yet for example, a 304 mm mesh size restriction applies to the entire province except for the Ottawa and St. Lawrence rivers where it is 254 mm.

The minimum legal size (dressed length) for commercially caught lake sturgeon in Ontario north of Lake Nipissing is 63 cm FL (≈110 cm TL). If the length-at-age range for age of maturity is estimated to be 72 cm to 124 cm TL then the current regulation cannot be considered effective in protecting brood stock.

CONSIDERATIONS FOR LAKE STURGEON COMMERCIAL FISHERY MANAGEMENT IN ONTARIO

The management of lake sturgeon commercial fisheries must be based on the following objectives:

1. manage for sustained yield;
2. ensure stock maintenance by protecting brood stock;
3. implement management initiatives that consider restoration of depleted populations;
4. protect and enhance lake sturgeon spawning and nursery habitat; and

5. determine if commercial fishing and sport fishing can coexist and then allocate harvest according to specific management concerns.

The brood stock component of the lake sturgeon population must be protected. Our discussion group proposed that smaller fish should comprise a considerable portion of the quota. This would also result in the harvest of fish with acceptable contaminant levels where contaminants are a problem. A quota based on annual landed weight may result in the capture of a few large fish, rather than increased numbers of fish. Brood stock can be protected by restrictions on gear (i.e. mesh sizes, hook-lines).

Additional protection could be acquired with size restrictions established by slot size limits if sufficient biological data are available for assessment. Although a slot limit application for the commercial fishery is not in place at this time, a slot limit might be considered in the range of 105 to 130 cm for some waters (Nowak and Jessop 1987). Slot size limits must be based on biological data available for a particular lake sturgeon population.

The selectivity of gill nets should be determined. With the exception of avoiding angler conflicts and incidental catch mortality, the length of gill nets used need not be a factor when harvest quotas are assigned. Our discussion group was concerned that for most fisheries, sufficient biological data may not be available to determine effective mesh size for brood stock protection. The effectiveness of baited hook-lines should also be evaluated with regard to harvest potential and the segment(s) of the population vulnerable to capture.

Considerations for gear restrictions, seasons, sanctuaries and maximum, minimum and slot size limits are all contingent upon determining annual harvest quotas. In order to determine quotas, reliable biological information must be utilized. The paucity of biological data and the variations in biomass estimates, estimated annual yield, mortality, length- and weight-at-age and ages of maturity occurring between watersheds and within water bodies presents a difficult challenge to the fisheries manager attempting to determine quota and its allocation. Sandilands (1987) reported that density and biomass estimates varied greatly among three stretches of the Kenogami River. Predictions of sustainable yield were not possible. The total annual mortality rate for the population in the study area was estimated at 4.6%. Sandilands suggested that the annual increase in biomass in the study area varied between 0.22 kg ha^{-1} and 1.3 kg ha^{-1}. The problems encountered during the Kenogami River project, with respect to small sample size, low confidence in population estimates and mortality rate, are similar to those encountered by many fisheries managers attempting to manage lake sturgeon. The problems translate into inability to approximate meaningful estimates of biomass and yield. Studies on the Groundhog River (Nowak and Jessop 1987) suggest an annual production of 3.97 kg ha^{-1}. Payne (1987) suggested that considerable variation in production occurred between years and areas of the three Cochrane District rivers studied. Annual production ranged from 0.17 on the Mattagami River to 0.94 kg ha^{-1} on the Frederick House River.

In order to implement management tactics, the manager must have some knowledge of the estimated lake sturgeon biomass for the water system, an estimate of the annual yield and data pertinent to age of maturity, length-at-age and weight-at-age. Acquiring this type of information for sturgeon management is not an easy task. Nowak and Jessop (1987) recognized the difficulty in determining the maximum allowable harvest which a sturgeon fishery can sustain. They report being unable to find evidence of successful sustained yield management for lake sturgeon in northern waters.

Determining age of maturity and length-at-age is an important requirement for managing commercial harvest of lake sturgeon. However, on many waters few data are available. Mosindy (1987) speculated that, based on mean ages at first maturity of 20 years for males and 25 years for females, more than 60% of the males and 65% of the females sampled from Lake of the Woods would be immature. Current catch quotas and recent biological data suggest that the present Lake of the Woods minimum size limits,

gear restrictions and reported harvest may not be conducive to rebuilding the sturgeon population. Sturgeon management, with a strategy intended to address a prolonged recovery period, might consist of protection of potential spawners and minimizing harvest of mature fish. Regulations to increase gillnet mesh size and minimum size for legal fish could be considered. The quota could be filled by a few large fish rather than a larger number of smaller fish. A lower rate of fishing mortality also ensures greater protection to the potential brood stock. Mosindy (1987) suggested that without a complete moratorium on sturgeon harvest in Lake of the Woods and Rainy River, a severe reduction in annual harvest quotas may be the only tactic available to allow for survival of brood stock.

Spawning lake sturgeon can be very vulnerable to harvest due to concentrations of fish during predictable time periods. Closed seasons are required and sanctuaries will have to be established to protect lake sturgeon populations in vulnerable locations. Dumont et al. (1987) suggested that restricting commercial fishing to designated areas within a water body is a positive sturgeon management tactic. Although subject to seasonal movement, the fish will receive some protection from commercial fishing effort while in closed areas.

The question of whether the commercial fishery and a sport fishery for sturgeon can co-exist was addressed. For many waters, a combination of commercial, sport and native subsistence harvest may exceed annual production. Licence conditions could eliminate harvest areas or a commercial licence could be refused. The commercial fishery could be closed and the sport fishery strictly regulated. The closure of the commercial fishery may have to be achieved through a buy-out process.

Sport fishing can have a commercial implication. Sturgeon taken legally by angling can also be legally sold by the angler. As sturgeon stocks are depleted and harvest restrictions increase, the dollar value for a scarce commodity will escalate. This has serious enforcement implications. An enforcement presence of sufficient capability must be available to act as a deterrent and to ensure punitive action when required, in order to protect sturgeon populations (Cook 1987).

Native subsistence fishing alone can have an overharvest impact on sturgeon stocks. Encouragement to target other species and provision of information stressing the critical state of a sturgeon population could result in establishing leadership within a band that would encourage management of the population through generally agreed upon harvest restrictions. Workshops for commercial fishermen can stress the importance of population management and harvest restrictions. The aid of fishermen in collecting data and recording observations can be recruited. Support for management initiatives comes from communication and awareness.

Lake sturgeon management throughout much of Ontario, particularly riverine systems, should be considered on a watershed basis. Analysis and evaluation of biological data may, in some cases, dictate that specific management tactics should be implemented for different waters within a watershed. This concept will necessitate negotiation between districts. Past experience suggests that once overexploitation of a lake sturgeon population has occurred, sturgeon stocks do not recover. With this in mind, the manager may have to either eliminate or refuse expansion of commercial fisheries for sturgeon.

A proposed revision to the Ontario Fishery Regulations has implications to the management of commercial species, including the lake sturgeon. The proposal would allow the manager, through a condition of licence, to specify such items as the species and size of fish which may be taken; individual quotas; the waters and periods of time in which a fishery may be conducted; the type of gear, mesh size, quantity and manner in which it may be used; and the specific location at which fishing gear may be set. This proposed revision, if implemented, will allow the manager to control harvest on an area and stock specific basis.

SUMMARY

In order to protect and manage lake sturgeon populations, and provide opportunities for commercial harvest, biological data are required on a stock specific basis. With appropriate information, quotas can be determined and gear restrictions applied that can result in protection of lake sturgeon brood stocks and perpetuation of sustained yields.

In some fisheries, the manager will have to discontinue commercial harvest or refuse to expand that segment of those fisheries targeting on lake sturgeon. Although these decisions will be difficult in the face of social, economic and perhaps political considerations, with historical stock and harvest information and current biological data, they can be shown to be defensible and justified. The identification, inventory and protection of lake sturgeon habitat must be implemented in conjunction with harvest controls and quota allocation.

The current regulations have not been adequate for either the protection and management of lake sturgeon fisheries, or for rebuilding depleted fisheries. The paucity of dependable and consistent biological data pertinent to lake sturgeon has compounded the problem of inadequate regulatory management capability. The proposed revision to the Ontario Fishery Regulations will provide managers with the capability to manage and protect lake sturgeon populations on an area and stock specific basis. This should ensure the continuation of a viable, but carefully controlled lake sturgeon commercial fishery.

RECOMMENDATIONS

1. Current commercial fish regulations in Ontario should be reviewed and altered to reflect the need for brood stock protection and realistic quota management.
2. Biological data pertaining to population dynamics and production should be collected on existing commercial lake sturgeon fisheries and used to adjust regulations where required.
3. Lake sturgeon commercial fisheries should be managed on a stock specific basis as much as possible.
4. In order to rebuild stocks, commercial fisheries for lake sturgeon should be curtailed in some areas.
5. Make explicit allocations of lake sturgeon to sport and commercial fishermen where necessary.

REFERENCES

BROUSSEAU, C. S. 1987. The lake sturgeon (*Acipenser fulvescens*) in Ontario, p. 2-9. *In* C.H. Olver [ed.] Proc. Workshop on the lake sturgeon (*Acipenser fulvescens*). Ont. Fish. Tech. Rep. Ser. No. 23. 99 p.

COOK, W. J. 1987. Enforcement implications for management of lake sturgeon (*Acipenser fulvescens*) in Ontario, p. 95-96. *In* C. H. Olver [ed.] Proc. Workshop on the lake sturgeon (*Acipenser fulvescens*). Ont. Fish. Tech. Rep. Ser. No. 23. 99 p.

DUMONT, P., R. FORTIN, G. DESJARDINS, and M. BERNARD. 1987. Biology and exploitation of lake sturgeon (*Acipenser fulvescens*) in the Québec waters of the Saint-Laurent River, p. 57-76. *In* C. H. Olver [ed.] Proc. Workshop on the lake sturgeon (*Acipenser fulvescens*). Ont. Fish. Tech. Rep. Ser. No. 23. 99 p.

MOSINDY, T. S. 1987. The lake sturgeon (*Acipenser fulvescens*) fishery of Lake of the Woods, Ontario, p. 48-56. *In* C.H. Olver [ed.] Proc. Workshop on the lake sturgeon (*Acipenser fulvescens*). Ont. Fish. Tech. Rep. Ser. No. 23. 99 p.

NOWAK, A. M., and C. S. JESSOP. 1987 Biology and management of the lake sturgeon (*Acipenser fulvescens*) in the Groundhog and Mattagami rivers, Ontario, p. 20-32. *In* C. H. Olver [ed.] Proc. Workshop on the lake sturgeon (*Acipenser fulvescens*). Ont. Fish. Tech. Rep. Ser. No. 23. 99 p.

PAYNE, D. A. 1987. Biology and population dynamics of lake sturgeon (*Acipenser fulvescens*) from the Frederick House, Abitibi and Mattagami rivers, Ontario, p. 10-19. *In* C. H. Olver

[ed.] Proc. Workshop on the lake sturgeon (*Acipenser fulvescens*). Ont. Fish. Tech. Rep. Ser. No. 23. 99 p.

SANDILANDS, A. P. 1987. Biology of the lake sturgeon (*Acipenser fulvescens*) in the Kenogami River, Ontario, p. 33-46. *In* C.H. Olver [ed.] Proc. Workshop on the lake sturgeon (*Acipenser fulvescens*). Ont. Fish. Tech. Rep. Ser. No. 23. 99 p.

MANAGEMENT OF LAKE STURGEON (*ACIPENSER FULVESCENS*) AS A SPORT FISH IN ONTARIO

J. R. Atkinson
Ontario Ministry of Natural Resources, Ontario Government Building, Box 5000, Thunder Bay, Ontario P7C 5G6

The lake sturgeon (*Acipenser fulvescens*) has potential to be managed as a sport fish in Ontario. Management involves habitat protection and rehabilitation, harvest control and population rehabilitation. Sturgeon numbers and range have been limited by overexploitation and habitat degradation. A new initiative in habitat protection and rehabilitation is recommended. More data are needed on the socio-economics of harvest and on sturgeon biology. Harvest control regulations, when undertaken, need an experimental management approach. Population rehabilitation will probably require intensive fish culture.

INTRODUCTION

At the lake sturgeon (*Acipenser fulvescens*) workshop in Timmins in 1986, a working group of managers and scientists from Ontario, Quebec and Minnesota produced a number of recommendations for the management of the lake sturgeon in Ontario. These recommendations are discussed within the context of sport fisheries management in Ontario.

CURRENT REGULATIONS

CREEL LIMITS

Creel limits are designed to limit the harvest of a particular species and to spread the catch amongst anglers. Ontario and Minnesota have creel limits of one lake sturgeon per angler per day. Quebec allows two per day; Michigan, two per season; Wisconsin and portions of British Columbia (with different species), one per season. Until recently, a creel limit of one per day in Ontario has probably been sufficient to control harvest. However, sport fishing for this species is becoming more popular throughout the province and, by 1984, the sport harvest of sturgeon exceeded the commercial harvest in Ontario (Brousseau 1987). On the Mattagami, Groundhog and Frederick House rivers in northern Ontario, angler interest and effort is increasing (Nowak and Jessop 1987; Payne 1987). Angler harvest from the Groundhog River exceeds or equals production at an exploitation rate of 5% (Nowak and Jessop 1987). Small stable sport fisheries exist for sturgeon in the St. Clair River and Rainy River. However, data are limited, partly because of the difficulty of contacting sport fishermen (G. Duckworth, Ontario Ministry of Natural Resources (OMNR), Chatham, Ont. N7M 5L8; W. Darby, OMNR, Fort Frances, Ont. P9A 1S4, pers. comm.).

It is difficult to assess the impact of sport fishing on sturgeon populations in Ontario, at the present time. The sturgeon is certainly much reduced in numbers, and the present sport harvest may be contributing to further population declines. Under the stress of increased sport fishing, a daily creel limit of one may be inadequate to meet management objectives.

MINIMUM SIZE LIMIT

In Ontario, there is no minimum size limit, except in fishing divisions 21 and 22 where the minimum size limit is 114 cm (total length, TL). The states of Minnesota and Michigan have minimum size limits of 114 and 127 cm, respectively. Minimum size limits are designed to allow adequate escapement to spawning size but, for many populations, data on maturity and fecundity are lacking (Mosindy 1987). From a management perspective, it is important to protect mature female sturgeon, since they mature later and spawn less frequently than males.

As well as late maturity, sturgeon are periodic spawners and may only spawn once every 5-7 years (Harkness and Dymond 1961). Using known age at first

maturity data presented at the Timmins workshop, and assuming a period of six years between spawning, it appears that female sturgeon have the potential to spawn 3-4 times between age 20 to 40.

SEASONS

Sport fishing for sturgeon is open all year in the Ontario Great lakes and connecting waterways as far east as Cornwall. It is open in fishing divisions 21 and 22 from June 30-May 14, from July 1-May 31 in Lake Nipissing (division 27) and from June 15-May 14 in the rest of the province. Mature and immature sturgeon congregate on the spawning grounds where they feed actively. Spawning usually occurs in June, depending on water temperatures and flow. Existing season closures are probably effective in allowing some, if not all, spawning to occur. However, sturgeon are still concentrated and readily caught when the season opens. The present closures, in combination with a daily creel limit of one, may not be sufficient to perpetuate or expand most existing fisheries, as increasing effort might result in overexploitation.

MANAGEMENT

Our working group, assigned the task of making management recommendations for sturgeon as a sport fish in Ontario, was faced with a number of problems; there is limited information on the biology of lake sturgeon in Ontario; data on maturity and fecundity are scarce; and the demand for sturgeon is thought to be increasing, but its extent is unknown. In this context, management alternatives were discussed for the rehabilitation of sturgeon populations.

CONTROL OF EXPLOITATION

Angler exploitation does not appear to be adversely affecting existing sturgeon populations in the province of Ontario except for a few local areas. A portion of the Groundhog River will soon be closed to fishing for part of the season, in order to reduce fishing pressure (Nowak and Jessop 1987). Where angling fisheries do exist, anglers fish for sturgeon in relatively small or well defined areas. Sturgeon concentrate in small areas in large numbers (Dumont et al. 1987) making them especially vulnerable to exploitation.

Additional regulation of the sport fishery does not appear to be urgent at present, except in certain areas. However, there is a need to identify other known concentrations of sturgeon and monitor them for signs of stress. Additional protection for sturgeon may become necessary if interest in angling continues to grow.

Sturgeon may become a more popular target species in the future because of their food value and their potential as a trophy. An increase in sport fishing could occur with attendant publicity of rehabilitated or newly accessed populations. In these cases, immediate harvest control is essential.

Sturgeon lend themselves to catch and release regulations because they are hardy and they have a very low natural mortality rate. A minimum size limit of 114 cm is in effect in fishing divisions 21 and 22. Data on age at maturity are not available on sturgeon populations from this area, but the usual length of sturgeon harvested by anglers from the Groundhog River is 110-130 cm (Nowak and Jessop 1987). If the size range of the catch is similar between the two areas, then a size limit of 114 cm would be of limited value, as the majority of the harvest would be above this limit. First spawning occurs in the Groundhog River when the fish are about 119 cm in length. Again, if this was the case for sturgeon populations in divisions 21 and 22, a minimum size limit of 114 cm would not ensure one spawning season. Assuming that maturity and harvest data are applicable, a minimum size limit of 120 cm would allow most sturgeon to spawn at least once before harvest. This regulation could reduce harvest significantly. A minimum size limit has the following advantages: it is easily understood; it is enforceable; if large enough, it ensures one spawning; and it may be possible to rebuild a depleted population. However, there are drawbacks in that it does not allow for harvest of fish that will die naturally; it could lead to reduced growth rates; and heavy fishing mortality is concencentrated on experienced spawners.

A harvested slot in which only fish within a specified size range may be retained was discussed by our working group. It has much to offer: it preserves the spawning population; it protects smaller fish; it allows for the harvest of 75% of the size range usually harvested by anglers (see Dumont et al. 1987). It has disadvantages in that there may be insufficient escapement to spawning size and the trophy kill aspect of the fishery is withdrawn.

Nowak and Jessop (1987) recommend a protected slot of 113-140 cm for sturgeon from the Groundhog River. In this method, only fish above and below a specified size range may be kept. Spawning populations are protected and a trophy kill is allowed, but escapement to the protected slot is not assured and the majority of the present harvest in Ontario using the 113-140 cm length range would be eliminated. Maximum size limits may also be a strategy to protect the brood stock, but this eliminates a trophy fishery. Maturity and fecundity studies may be required to set and maximize the benefits of size limits for individual populations.

Due to the lack of socio-economic data on the desirability and value of sport fishing for sturgeon, it is difficult to make provincial management recommendations for harvest control. Our working group recommended a provincial protected slot of 100-140 cm (TL). However, on reflection, this appears to be premature. We did not specifically recommend any changes to existing seasons and limits, but agreed that in some areas these mechanisms of harvest control should be examined.

HABITAT

Sturgeon populations have declined in Ontario and Quebec in the past 100 years due in part to habitat deterioration. Dams and associated changes in water quality levels and flow regimes have limited sturgeon range and reduced numbers (Payne 1987). Impairment of water quality has also reduced sturgeon numbers (Dumont et al. 1987).

The protection and rehabilitation of sturgeon habitat should be made a priority. Liaison with utilities and industry should be established by the field organizations of the appropriate Ontario government ministries. If this does not result in quantifiable improvements in habitat, relevant legislation should be enforced to protect and rehabilitate existing habitat.

STOCKING

Given their history of overexploitation, rehabilitation of sturgeon populations is unlikely, or will be a very slow process if the only mechanisms are harvest control and habitat protection. Sturgeon populations have remained depressed long after commercial fisheries were closed (Brousseau 1987). An alternative to this approach to sturgeon rehabilitation is to institute a stocking program. Intensive sturgeon culture has been carried out successfully in Russia and the United States (Anderson 1984). Our working group recommended that an experimental, intensive culture and stocking program of sturgeon be considered for one area of the province.

MANAGEMENT RECOMMENDATIONS

1. More data, specifically on maturity, spawning frequency, fecundity, growth and behaviour, should be acquired.
2. A mail survey should be carried out to determine the demand for sport fishing for sturgeon.
3. The lake sturgeon should be promoted as a trophy sport fish throughout Ontario.
4. The minimum size limit for sturgeon, where applicable in Ontario, should be reassessed and consideration should be given for a more general implementation.
5. Protected or harvested slot size limits and maximum size limits should be carefully considered and experimentally tried on selected populations.
6. The provincial creel limit of one per day should be reviewed with the aim of making it more restrictive in problem areas.
7. Sturgeon habitat should be mapped, protected and, where necessary, rehabilitated.
8. Consideration should be given to an experimental rehabilitation program of a sturgeon population through intensive fish culture.

REFERENCES

ANDERSON, E. R. 1984. Artificial propagation of lake sturgeon (*Acipenser fulvescens* Rafinesque) under hatchery conditions in Michigan. Mich. Dep. Nat. Resour., Fish. Div., Fish. Res. Rep. 1898. 32 p.

BROUSSEAU, C. S. 1987. The lake sturgeon (*Acipenser fulvescens*) in Ontario, p. 2-9. *In* C.H. Olver [ed.] Proc. Workshop on the lake sturgeon (*Acipenser fulvescens*). Ont. Fish. Tech. Rep. Ser. No. 23. 99 p.

DUMONT, P., R. FORTIN, G. DESJARDINS, and M. BERNARD. 1987. Biology and exploitation of lake sturgeon (*Acipenser fulvescens*) in the Quebec waters of the Saint-Laurent River, p. 57-76. *In* C.H. Olver [ed.] Proc. Workshop on the lake sturgeon (*Acipenser fulvescens*). Ont. Fish. Tech. Rep. Ser. No. 23. 99 p.

HARKNESS, W. J. K., and J. R. DYMOND. The lake sturgeon. Ont. Dep. Lands Forests, Fish. Wildl. Br., Toronto. 121 p.

MOSINDY, T. S. 1987. The lake sturgeon (*Acipenser fulvescens*) fishery of Lake of the Woods, Ontario, p. 48-56. *In* C. H. Olver [ed.] Proc. Workshop on the lake sturgeon (*Acipenser fulvescens*). Ont. Fish. Tech. Rep. Ser. No. 23. 99 p.

NOWAK, A. M., and C. S. JESSOP. 1987. Biology and management of the lake sturgeon (*Acipenser fulvescens*) in the Groundhog and Mattagami rivers, Ontario, p. 20-32. *In* C. H. Olver [ed.] Proc. Workshop on the lake sturgeon (*Acipenser fulvescens*). Ont. Fish. Tech. Rep. Ser. No. 23. 99 p.

PAYNE, D. A. 1987. Biology and population dynamics of lake sturgeon (*Acipenser fulvescens*) from the Frederick House, Abitibi and Mattagami rivers, Ontario, p. 10-19. *In* C. H. Olver [ed.] Proc. Workshop on lake sturgeon (*Acipenser fulvescens*). Ont. Fish. Tech. Rep. Ser. No. 23. 99 p.

ENFORCEMENT IMPLICATIONS FOR MANAGEMENT OF LAKE STURGEON (*ACIPENSER FULVESCENS*) IN ONTARIO

W. J. Cook
Ontario Ministry of Natural Resources, Box 3000, Cochrane, Ontario P0L 1C0

INTRODUCTION

In the past, little emphasis has been placed on the management of lake sturgeon (*Acipenser fulvescens*) in Ontario. This has been particularly true for the sport fishery where the lack of data has been even more acute than for the commercial fishery. Until recently, interest in recreational fishing for sturgeon has been low, and the use of the resource by anglers has not posed many enforcement problems with existing regulations. Consequently, enforcement of sport fishing regulations for sturgeon has not been a priority.

Populations have been overexploited commercially, particularly in the Great Lakes and in northern Ontario (Brousseau 1987; Payne 1987). The demand for sturgeon flesh and caviar has greatly increased across the province to the extent that the use of illegal methods for harvesting, transporting, selling and record keeping is increasing. Various steps must be taken immediately to protect existing sturgeon populations.

Increased awareness about the problems facing lake sturgeon populations (Brousseau 1987; Hart 1987) must be communicated to both managers and users of the resource. The fragile nature of the species requires an educational program in order to change priorities of fishery managers and to make commercial and sport fishermen aware of the need for more restrictive harvest controls.

Enforcement problems, with respect to present legislation, must be well defined on a regional basis. Intelligence must be gathered on commercial fisheries outlining specific situations, procedures and problems concerning licencees, locations of licences, quotas, buyers, locations, transport methods, returns, native catch, harvest methods and perceived opportunities for illegal operations. Where sport fisheries exist, data on harvest levels and illegal operations should be collected.

A lake sturgeon enforcement plan is required. As this would be a new initiative with little extra support, the elements of the plan must concentrate on problem areas. In addition to the development of an intelligence base, the plan should address licencing requirements, harvest methods, audit procedures and legislation.

LICENCING REQUIREMENTS

Geographic locations and special conditions must be described so that they are enforceable. The fishery officer issuing such licences must be cognizant of sturgeon management problems, either through personal knowledge or regionally available expertise. Should a commercial fisherman hold more than one licence, each should be issued for different time periods with mandatory returns necessary after each period prior to approval to fish the next area. This would ensure quotas are from the proper licence area.

HARVEST METHODS

Methods for ensuring compliance to gear restrictions should be developed. Few staff are experienced with sturgeon harvesting methods. Field training should be given to at least one staff member in each district which licences commercial fisheries for sturgeon.

AUDIT PROCEDURES

Audit procedures presently are well defined on a general basis for com-

mercial fishing activities. However, there are some buyers in North America who only deal in sturgeon. Audit procedures should be developed in detail for individual buyers.

LEGISLATION

Problems in enforcing present legislation should be addressed by staff who are knowledgeable about sturgeon. It is expected that areas of scrutiny would include quota definition, quota control and transportation. Enforcement officers and commercial fishermen alike have difficulty with weight and length (dressed/round) conversions. Total numbers and length may be a simpler alternative. A tag system could be considered to ensure that the fish reported harvested are from the licenced area. Numbered tags corresponding to the quota number of sturgeon could be issued to the licencee for the licence area. A non-removable tag (i.e. jaw tag placed on the dorsal fin) would be attached to each sturgeon after capture and remain there until processing. For inspection purposes, tags would have to be applied at the fishing site. Mandatory reporting of transportation routes and time previous to shipment are suggested. Sturgeon should be shipped in total length with dressing allowed.

Other elements requiring regulation will no doubt occur with an in-depth review. The results and recommendations of this review should be scrutinized jointly by commercial fishermen, sport fishermen and managers.

In summary, a new initiative is required in order to establish and enforce adequate controls to manage lake sturgeon populations as demand increases. With the high market value of this species, it should follow that adequate emphasis be exerted to control and preserve lake sturgeon in Ontario.

RECOMMENDATIONS

1. A communications plan should be developed to make managers and the public more aware of the sensitive nature of the lake sturgeon.
2. A data base should be collected on commercial and sport fisheries.
3. Lake sturgeon enforcement plans should be developed on a regional basis concentrating on licencing requirements, harvest methods, audit procedures and present legislation problems.

REFERENCES

BROUSSEAU, C. S. 1987. The lake sturgeon (*Acipenser fulvescens*) in Ontario, p. 2-9. *In* C.H. Olver [ed.] Proc. Workshop on the lake sturgeon (*Acipenser fulvescens*). Ont. Fish. Tech. Rep. Ser. No. 23. 99 p.

HART, M. L. 1987. Considerations for the management of lake sturgeon (*Acipenser fulvescens*) commercial fisheries in Ontario, p. 85-90. *In* C. H. Olver [ed.] Proc. Workshop on the lake sturgeon (*Acipenser fulvescens*). Ont. Fish. Tech. Rep. Ser. No. 23. 99 p.

PAYNE, D. A. 1987. Biology and population dynamics of lake sturgeon (*Acipenser fulvescens*) from the Frederick House, Abitibi and Mattagami rivers, Ontario, p. 10-19. *In* C. H. Olver [ed.] Proc. Workshop on the lake sturgeon (*Acipenser fulvescens*). Ont. Fish. Tech. Rep. Ser. No. 23. 99 p.

APPENDIX A. Workshop Participants

K.F. Abraham
Ontario Ministry of Natural Resources
P.O. Box 190
Ontario Government Building
Reveillon Road
Moosonee, Ontario P0L 1Y0

E.R. Anderson
Minn. Department of Natural Resources
Section of Fisheries
1200 Warner Road
St. Paul, Minnesota 55106

E.W. Armstrong
Ontario Ministry of Natural Resources
P.O. Box 640
208 Beamish Avenue West
Geraldton, Ontario P0T 1M0

J.R. Atkinson
Ontario Ministry of Natural Resources
P.O. Box 5000
Ontario Government Building
435 James Street South
Thunder Bay, Ontario P7C 5G6

S.G. Aubry
Ontario Ministry of Natural Resources
P.O. Box 730
2 Third Avenue
Cochrane, Ontario P0L 1C0

M. Bernard
Ministère du Loisir,
de la Chasse et de la Pêche
100 Rue Laviolette
3ième étage
C.P. 187
Trois Rivieres, Québec G9A 5S9

A.R. Bowman
Aquatic Ecostudies Limited
1384 Marcel Street
Sudbury, Ontario P3E 4G3

C.S. Brousseau
Ontario Ministry of Natural Resources
P.O. Box 3000
Cochrane, Ontario P0L 1C0

L.C. Chamberlin
Ontario Ministry of Natural Resources
P.O. Box 129
Swastika, Ontario P0K 1T0

D. Choquette
Ministère du Loisir,
de la Chasse et de la Pêche
Charlesbourg, Québec G1G 5H9

W.J. Cook
Ontario Ministry of Natural Resources
P.O. Box 640
208 Beamish Avenue West
Geraldton, Ontario P0T 1M0

C.D. D'Amour
Ontario Ministry of Natural Resources
P.O. Box 730
2 Third Avenue
Cochrane, Ontario P0L 1C0

J.J. Danyluck
Ontario Ministry of Natural Resources
190-192 Cherry Street
Chapleau, Ontario P0M 1K0

F.N. Dawson
Ontario Ministry of Natural Resources
P.O. Box 670
631 Front Street
Hearst, Ontario P0L 1N0

P. Dumont
Ministère du Loisir,
de la Chasse et de la Pêche
Direction Régionale de Montréal
6255 13ième Avenue
Montréal, Québec H1X 3E6

R. Fortin
Ministère du Loisir,
de la Chasse et de la Pêche
1200 Saint-Alexandre
4ième étage
4090 La Place Desjardins
Montréal, Québec

H. Fournier
Ministère du Loisir,
de la Chasse et de la Pêche
13 Rue Buteau
Hull, Québec J8Z 1V4

G.A. Goodchild
Ontario Ministry of Natural Resources
Whitney Block, Room 2347
99 Wellesley Street West
Toronto, Ontario M7A 1W3

R.H. Hamilton
Ontario Ministry of Natural Resources
P.O. Box 5000
Ontario Government Building
435 James Street South
Thunder Bay, Ontario P7C 5G6

M.L. Hart
Ontario Ministry of Natural Resources
P.O. Box 605
Oxford Avenue
Brockville, Ontario K5V 5V8

R.J. Jackson
Ontario Ministry of Natural Resources
P.O. Box 730
2 Third Avenue
Cochrane, Ontario P0L 1C0

C.S. Jessop
Ontario Ministry of Natural Resources
6-8-10 Government Road
Kapuskasing, Ontario P5N 2W4

P. Leclerc
Ministère du Loisir,
de la Chasse et de la Pêche
Université du Québec
1200 St. Alexandre
4ième étage
4090 La Place Desjardins
Montréal, Québec

G.M. Leering
Ontario Ministry of Natural Resources
P.O. Box 129
Swastika, Ontario P0K 1T0

E.H. Lucking
Ontario Ministry of Natural Resources
896 Riverside Drive
Timmins, Ontario P4N 3W2

V. Macins
Ontario Ministry of Natural Resources
P.O. Box 5160
810 Robertson Street
Kenora, Ontario P9N 3X9

T.E. Mosindy
Ontario Ministry of Natural Resources
Lake of the Woods Assessment Unit
P.O. Box 5000
Kenora, Ontario P9N 3X0

D. Nadeau
Ministère du Loisir,
de la Chasse et de la Pêche
180 Boulevard Rideau
Noranda, Québec J9X 1N9

A.M. Nowak
Ontario Ministry of Natural Resources
P.O. Box 730
Cochrane, Ontario P0L 1C0

C.H. Olver
Ontario Ministry of Natural Resources
P.O. Box 9000
Brendale Square
Huntsville, Ontario P0A 1K0

D.A. Payne
Ontario Ministry of Natural Resources
P.O. Box 730
Cochrane, Ontario P0L 1C0

R.D. Phoenix
Ontario Ministry of Natural Resources
P.O. Box 129
Low Avenue
Gogama, Ontario P0M 1W0

M.J. Picotte
Ontario Ministry of Natural Resources
896 Riverside Drive
Timmins, Ontario P4N 3W2

C. Pomerleau
Direction generale de la faune
150, St.-Cyrille, est
Québec, Québec G1R 4Y1

L. Roy
Ministère de Loisir,
de la Chasse et de la Pêche
Charlesbourg, Québec G1G 5H9

A.P. Sandilands
Ecologistics Limited
50 Westmount Road North
Waterloo, Ontario N2L 2R5

H. Schachow
Ontario Ministry of Natural Resources
P.O. Box 670
631 Front Street
Hearst, Ontario P0L 1N0

J.C. Tilt
Ontario Ministry of Natural Resources
Whitney Block, Room 2347
99 Wellesley Street West
Toronto, Ontario M7A 1W3

P.W. Varrin
Ontario Ministry of Natural Resources
190-192 Cherry Street
Chapleau, Ontario P0M 1K0

M.F. Vukelich
Ontario Ministry of Natural Resources
P.O. Box 670
631 Front Street
Hearst, Ontario P0L 1N0

J.M. Warris
Ontario Ministry of Natural Resources
Whitney Block, Room 2347
99 Wellesley Street West
Toronto, Ontario M7A 1W3

N.C. Wilson
Ontario Ministry of Natural Resources
P.O. Box 730
2 Third Avenue
Cochrane, Ontario P0L 1C0

ONTARIO FISHERIES TECHNICAL REPORT SERIES

No. 6 Survival and growth of matched plantings of lake trout (*Salvelinus namaycush*), brook trout (*Salvelinus fontinalis*), and lake x brook F_1 splake hybrids in northeastern Ontario lakes.
P.E. Ihssen, M.J. Powell and M. Miller. 1982.

No. 7 The performance of two wild and two hybrid strains of brook trout planted in an infertile, acidic lake.
J.M. Fraser. 1983.

No. 8 Decomposition of wild rice (*Zizania aquatica L.*) straw and its effect on the depletion of oxygen during winter in natural lakes of northwestern Ontario.
Pritam Sain. 1983.

No. 9 Annulus formation and growth characteristics of tagged walleye in a lightly exploited lake.
D. Baccante and J. Sandhu. 1983.

No. 10 An evaluation of climatic, morphoedaphic, and effort data as predictors of yields from Ontario sport fisheries.
D.A. Schlesinger and A.M. McCombie. 1983.

No. 11 An annotated listing of original field data books and diaries of Ontario fisheries research laboratory workers (1921-1948).
D.O. Evans and B.A. Campbell. 1984.

No. 12 A selective biography of the lake trout, *Salvelinus namaycush* (Walbaum), 1784-1982.
C.H. Olver and N.V. Martin. 1984.

No. 13 Sport fisheries in the Canadian portion of Lake Erie and connecting waters, 1948-1980.
L.K. Sztramko and J.R. Paine. 1984.

No. 14 Distribution and characteristics of spawning round whitefish in Lake Ontario, 1976-1981.
G.T. Haymes and D.P. Kolenosky. 1984.

No. 15 The effects of depth and harvest on bait fish in southern Ontario streams.
C.B. Portt. 1985.

No. 16 Early life studies of lake whitefish (*Coregonus clupeaformis*), cisco (*Coregonus artedii*) and yellow perch (*Perca flavescens*) in Lake Opeongo, Ontario.
D. Cucin and D.J. Faber. 1985.

No. 17 The sensitivity of Ontario lake trout (*Salvelinus namaycush*) and lake trout lakes to acidification.
G.L. Beggs, J.M. Gunn, and C.H. Olver. 1985.

No. 18 Movements of rainbow trout (*Salmo gairdneri*) and splake (*Salvelinus fontinalis* x *S. namaycush*) in a small Ontario lake as revealed by ultrasonic telemetry.
G. Betteridge. 1985.

No. 19 The Lake Opeongo creel survey.
M.J. McMurtry and B.J. Shuter. 1985.

No. 20 Water drawdown and its effects on lake trout (*Salvelinus namaycush*) reproduction in three south-central Ontario lakes.
M.L. Wilton. 1985.

No. 21 Standing stock estimates of benthic fauna for a lake set in northwestern Ontario.
K.I. Cullis. 1986.

No. 22 Returns of hatchery-reared lake trout from eight lakes in northeastern Ontario.
M.J. Powell, M.-F. Bernier, S.J. Kerr, G. Leering, M. Miller, W. Samis and M. Pellegrini. 1986.